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THE SCHOOL OF MINES QUARTERLY.

INDEX, VOL. XIX.

November, 1897, to July, 1898.

All Abstracts are printed in Italics, and those relating to Metallurgy or to Chemical Analysis appear only under the headings Metallurgy and Analytical Chemistry.

ALUMNI AND UNIVERSITY NEWS.

Departments:

PAGE

Architecture 104
Chemistry 219
Electrical Engineering 102
Geology 104, 327
Metallurgy 97, 438
Mining 101
Physics 106

Analytical Chemistry, Abstracts

Acidimetric Determination of Phosphoric Acid 223
Adulterants of Portland Cement 325
Alkalimetric Indicator 427
Alkalimetry, etc., Applied to Metals 316
Alkaline Carbonates 210
Alloys for Metal Bearings 326
Alumina and Ferric Oxide in Phosphates 316, 429
Alumina in Bauxite 428
Alluminum Citrate Solution 209
Aluminum as an Electrode 427
Aluminum, Phosphides 434
Analyses of Silicates 436
Analyses of Iron and Steel 211
Available Alumina 428
Barium Thiosulphate for Standardizing 209
Basic Slags 435
Bichromate Titration 429
Boric Acid 435
Bronze and Brass 325
Bronze and Brass Electrolitic 326
Calcium Carbide 436
Carbon in Ferro Chrome 218
Carbon in Irons 435
Carbon Monoxide 321

Digitized by Google

Carbonic Acid in Natural Waters 322
Corbonic Acid in Sodium Bicarbonate 436
Chrome Steel Analyses 429
Coal Analyses 325, 436
Colorimetric for Disulphuric Acid 216
Colorimetric for Silica in Waters 436
Commercial Sodium Sulphide 324
Commercial Sulphur Chloride 323
Condition of Elements in Steel 218
Copper by the Iodine Method 213
Copper Estimation 318
Copper in Bearing Metal Alloys 319
Detecting Potassium 210
Detecting traces of Bromine 215, 321
Determination of Boric Acid 217
Determination of Iron and Alumina in Phosphate 211
Determination of Phosphoric Acid 324
Determining Phosphine in Acetylene Gas 434
Disolving Platinum 318
Distilling of Bromine 215
Electrolytic Analysis of Bronze and Brass 212
Estimating Nitrates 324
Estimating Potassium 316
Estimating Tin and Stannic Salts 430
Estimation of Sulphuric Acid 215
Estimation of Tin 430
Ferric Oxide 428
Filter Papers 427
Flocculation in Laboratory Work 315
Free Alumina 428
Halogens in Mineral Waters 214
Incandescent Mantles 431
Insoluble Phosphorus in Iron Ores 324
Interaction of Thiosulphates with Cyanides 435
Iron and Steel 325
Iron by Hydrogen 429
Iron in Ores 317
Lead in Drinking Waters 431
Manganese Electrolytic 430
Manganese in Plants and Soils 429
Mineral Matter in Rubber Goods 326
Moisture 428
Molybdate Reagent 209
Nickel in Nickel Steels 317
Nickel in Steels 212
Nitrous Acid in Waters 218
Percarbonates 209
Perchlorate in Chili Saltpetre 433
Phosphoric Acid 217, 434
Phosphorus in Steel 323
Possible New Element 219
Potassa or Soda Purified by Alcohol 209
Potassium Determination 211, 428
Preservation of Titrated Permanganate Solutions 209
Pure Cerium Oxide 213
Pure Copper for Analytical Work 427
Pure Hydrofluoric Acid 209
Pure Oxalic Acid for Standardizing 210
Qualitative for Arsenic and Antimony 317
Qualitative Separation of the Halogens 321

Digitized by Google

Reagent for Nitrous Acid 218
Reduction of SO_2 to H_2S 215
Refined Copper 319
Selenium and Tellurium 320
Separating Tin, Arsenic and Antimony 317
Separation and Estimation of Lead 431
Separation of Aluminum and Beryllium 211
Separation of Arsenic 430
Separation of Arsenic from Antimony 212
Separation of Chlorine and Bromine 214
Separation of Mercury from Bismuth 431
Separation of Thorium 432
Separation of Thorium and Cerium Acids 213
Silver, Scorification instead of Cupellation 320
Silver in Silver Plating Solutions 213
Sodium Bicarbonate 316
Solid Matter in the Air 326
Standardizing Alkalimetric Solutions 210
Sulphates in Potable Waters 322
Sulphide and Sulphydrate of Sodium 435
Sulphur Monochloride 438
Sulphur in Bitumen 322
Sulphur in Coal 322
Sullphuric Acid and Lime in Waters 437
Tellurium—Idometric Method 433
Test for Water 437
Testing Paints 438
Thorium 214
Thorium Determinations 214
Tin in the Plate 430
Titanium Oxide 428
Titration of Sodium Thiosulphate 215
Titration of Stannous Salts 318
Vanadium Estimations 320
Volumetric for Antimony 318
Volumetric for Phosphoric and Arsenic Acids 217
Volumetric for Sodium 427
Volumetric for Zinc by Ferrocyanides 211
Yttria Earths of Monazite and Æschinite 431
Zinc Titration 317
Assay of Telluride Ores, The. Charles H. Fulton 419
Ballistic Galvanometer and Some of Its Applications. W. H. Freedman 392
Between the Mine and the Smelter. Albert R. Ledoux 358
Blast Furnaces, Management of. E. S. Cook 227
BOGERT, MARSTON TAYLOR. *Carbon Compounds Used in Medicine* 47
BOOK REVIEWS:
A Description of Minerals of Commercial Value. D. M. Barringer, A.M., LL.B. 226
Applied Mechanics. John Perry, M.E., D.Sc., F.R.S. 223
Elements of the Differential and Integral Calculus, with Applications. William S. Hall 440
Elements of Theoretical Physics. Dr. C. Christiansen 328
Fuel and Refractory Materials. A. Humboldt Sexton 109
Glaciers of North America. Israel C. Russell 107
High Masonry Dams. E. Sherman Gould 224
Manual of Hydraulic Mining for the Use of the Practical Miner. T. F. Van Wagenen, E.M. 225
Manual of Qualitative Chemical Analysis. Dr. C. Remigius Fresenius 111

Digitized by Google

Notes on Lead and Copper Smelting and Copper Converting. Hiram W. Hixon 112
The Alternating Current Circuit. W. Perren Maycock 110
The Induction Coil in Practical Work. Louis Wright 225
The Mineral Industry, Its Statistics, Technology and Trade in the United States and other Countries to the end of 1896, Vol. V. Edited by R. P. Rothwell 111
The Stamp Milling of Gold Ores. T. A. Rickard 110
Volcanoes of North America. Israel C. Russell 107
BROWN, R. G. *A Mineralized Dyke* 90
BURR, WM. H. *The Theory of the Circular Dome of Uniform Varying Thickness* 1
Tests of Full Sized Cast Iron Columns 283
Carbon Compounds used in Medicine. Classified according to Chemical Structure. Marston Taylor Bogert 47
Chronology of the Mississippi System, The. James L. Greenleaf 296
Cleps-Tachymeters, The. C. McK. Lewis 150
Circular Masonry Dome of Uniformly Varying Thickness, The Theory of the. Wm. H. Burr 1
COOK, E. S. *Management of Blast Furnaces* 227
Condition in which Zinc Exists in Slag, The. Malvern W. Iles 197
Corrected Assays. Contributions from the Analytical Laboratories of Columbia University. Edmund H. Miller 43
CROCKER, FRANCIS B. *Electcical Engineering at Columbia University* 175
DEVEREUX, W. B. *Notes on the Present Western Practice of Metallurgy. Economically Considered, II* 35
Electrical Engineering at Columbia University. Francis B. Crocker 175
Fan Pump, The. A Special Instance of Its Use for Mill Water Supply. F. C. Cooper, Met.E 194
FREEDMAN, WILLIAM H., E.E. *The Ballistic Galvanometer* 392
FULTON, CHARLES H. *The Assay of Telluride Ores* 419
GREENLEAF, JAMES L. *The Chronology of the Mississippi System* 296
Heating and Ventilating of Columbia University, The. G. A. Suter 329
HOOPER, F. C. *The Fan Pump. A Special Instance of its Use for Mill Water Supply* 194
ILES, MALVERN WELLS. *The Condition in which Zinc Exists in Slag* 197
LEDOUX, ALBERT R., A.M., M.S., Ph.D. *Between the Mine and the Smelter* 358
LEWIS, C. MCK. *The Cleps-Tachymeter* 150
Liquid Air, Its Production and Properties. Samuel A. Tucker 344
LUQUER LEA MCI., Ph.D. *Optical Scheme* 93
Metallurgy, Abstracts in.
Aluminum and other Metals 314
Bessemer Steel 310
Blast Furnace Practice 307
Copper 311
Fluxes 306
Foundry Practice 307
Fuel 305
Furnaces 305
Gold 312
Lead 311
Open Hearth Steel 310
Ores of Iron 306
Properties of Pig Iron 306
Pyrometry 306

Digitized by Google

Refractory Materials 305
Steel : Physical Properties 308
MILLER, EDMUND H. *Contributions from the Analytical Laboratories of Columbia University. Corrected Assays* 43
MILLER, SAMUEL OSGOOD. *A straight line formula for Cast-Iron Columns*.... 185
Mineral Properties. Notes on the Exploration of. Henry S. Munroe..... 9
Mineralized Dyke. R. G. Brown..... 90
Minor Planets, The. John K. Rees..... 248
MOSES, ALFRED J., Ph.D. *An Introduction to the Study and Experimental Determination of the Characters of Crystals*.....14, 113, 260, 374
MUNROE, HENRY S. *Notes on the Exploration of Mineral Properties*..... 9
NEWBROUGH, W. *A Water Measuring Box*..... 88
Optical Scheme. Lea McI. Luquer, Ph.D 93
Physical Tests of New York Shales. Heinrich Ries, Ph.D..... 192
Power Consumption on the Lenox Avenue Conduit Electric Road, New York City. G. F. Sever..... 200
Present Western Practice of Metallurgy.—Economically Considered. II, Notes on the. W. B. Devereux..... 35
REES, JOHN K. *The Minor Planets*..... 248
RIES, HEINRICH, Ph.D. *Physical Tests of New York Shales*..... 192
School of Architecture in its New Quarters, The. W. R. Ware 289
SEVER, G. F. *Power Consumption on the Lenox Avenue Conduit Electric Road, New York City*.. 200
Sliding Stadia Rod, A. Gilbert Thompson..... 302
Straight-Line Formula for Cast-Iron Columns, A. Samuel Osgood Miller..... 185
STRUTHERS, JOSEPH, Ph.D. *Abstracts in Metallurgy*..... 305
Study and Experimental Determination of the Characters of Crystals. An Introduction to the. Alfred J. Moses, Ph.D..... .14, 113, 260, 374
SUTER, G. A. *The Heating and Ventilation of Columbia University*..... 329
System in the Location of Mining Districts. Theo. F. Van Wagenen 189
Tests of Full-Sized Cast-Iron Columns. Wm. H. Burr..... 283
THOMPSON GILBERT. *A Sliding Stadia Rod*..... 302
TUCKER, SAMUEL A. *Liquid Air, Its Production and Properties*..... 344
VAN WAGENEN, THEO. F., E.M. *System in the Location of Mining Districts*.. 189
WALLER, ELWYN. *Abstracts in Analytical Chemistry*.....209, 315, 427
WARE, WILLIAM R. *The School of Architecture in Its New Quarters*..... 289
Plates for Same..... 441
Watering-Measuring Box, A. W. Newbrough..... 88

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VOL. XIX. No. 1. NOVEMBER, 1897.

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CONTENTS:

The Theory of the Circular Masonry Dome of Uniformly Varying Thickness. By Wm. H. Burr 1
Notes on the Exploration of Mineral Properties. By Henry S. Munroe 9
An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D 14
Notes on the Present Western Practice of Metallurgy—Economically Considered. II. By W. B. Devereux 35
Contributions from the Analytical Laboratories of Columbia University —Corrected Assays. By Edmund H. Miller 43
Carbon Compounds used in Medicine. Classified According to Chemical Structure. By Marston Taylor Bogert 47
A Water Measuring Box. By W. Newbrough 88
A Mineralized Dyke. By R. G. Brown 90
Optical Scheme. By Lea McI. Luquer, Ph.D. 93
Alumni and University News 97
Book Reviews 107

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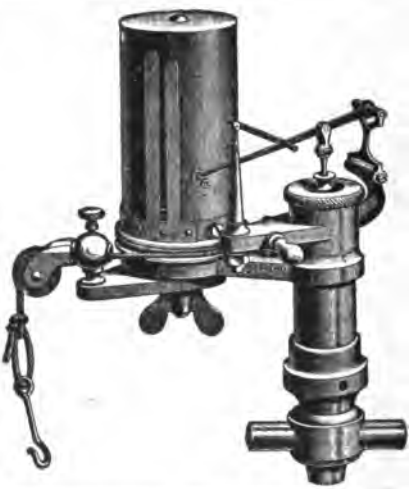

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THE THEORY OF THE CIRCULAR MASONRY DOME OF UNIFORMLY VARYING THICKNESS.

BY WM. H. BURR.

Masonry domes have rarely been constructed in this country until a very recent period and, hence, the theory of such structures has not received general attention among civil engineers and architects. The theory of domes of all suitable shapes of vertical section is no new subject among those engineers who have been in the habit of making quantitative investigations in connection with masonry structures in general, but the accurate expressions for the stresses in a dome of varying thickness are not easily accessible. Inasmuch as the best design requires the thickness to vary, it is of practical importance to determine the analytical expressions to be employed in such design, and that observation receives emphasis from the fact that the masonry domes thus far designed or constructed in this country have usually been built with a sensibly uniformly varying thickness and with a vertical section either circular or so nearly so that a theory for a circular section can be made to fit the case without material error. In this investigation, therefore, the formulæ to be established will be those belonging to the circular section, although formulæ for any other vertical section can be deduced by the same general method.

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In Fig. 1, *A B C* is the circular center line with the radius *r* of a circular segmental dome. Let *a* be the thickness of the shell of the

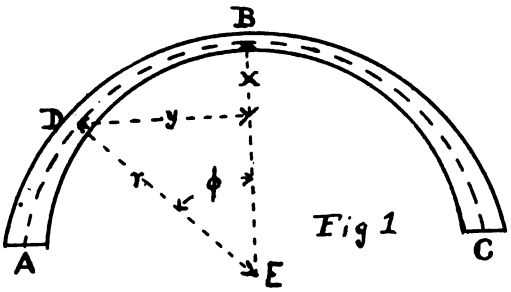

Fig 1

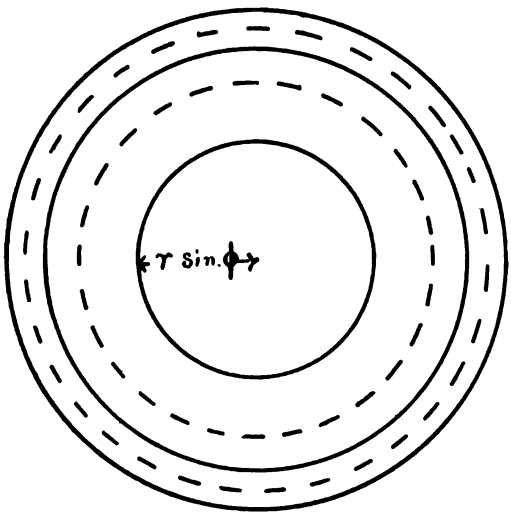

Fig 2.

dome at the crown, *B*, and as the thickness of the shell is to vary uniformly as the distance from the crown, let *c* be such a constant that the thickness *t* at any ring, as *D*, will be:

$$t = a + r\varphi c \qquad (1)$$

As shown in Fig. 1, φ is the angular distance of the ring considered from the vertical axis of the dome. The coördinates *x* and *y* locate the centre of any ring from the crown as an origin. It will be desirable first to determine the volume, *V*, of any portion of the dome above the ring located by *x* and *y*. The section of an

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elementary ring of the dome will be $rd\varphi.t$, and its circumference will be $2\pi r \sin \varphi$. Hence the volume of this elementary ring will be the product of these two quantities, or:

$$dV = 2\pi r^2 \sin \varphi (a + cr\varphi) d\varphi$$

The volume of that portion of the dome between the crown and the ring at the angular distance φ from it will then be:

$$V = 2\pi r^2 \int_0^{\varphi} (a \sin \varphi \, d\varphi + cr \sin \varphi \, . \varphi \, . d\varphi)$$

$$\therefore \quad V = 2\pi r^2 [a(1 - \cos \varphi) + cr(\sin \varphi - \varphi \cos \varphi)] \qquad (2)$$

If w is the weight of a cubic unit of the masonry, the weight of the volume given by equation (2) will be:

$$W = wV. \qquad (3)$$

If it be assumed that the joints are perfectly fitted and that all parts of the dome are in complete stability, which two assumptions must be attained as nearly as practicable in an actual design, the total or resultant pressure on any circular ring joint may be taken as uniformly distributed and as having a direction tangential to the dome, *i. e.*, normal to the joint. That total or resultant pressure will be equal to the weight of the dome above the joint multiplied by the secant of the inclination of the dome at the joint to a vertical line, *i. e.*, it will be equal to

$$P_i = wV \operatorname{cosec} \varphi = 2\pi r^2 w [a(\operatorname{cosec} \varphi - \operatorname{cotan} \varphi) + cr(1 - \varphi \operatorname{cotan} \varphi)]. \qquad (3a)$$

The total outward radial (horizontal) pressure around the ring will be the horizontal component of the preceding expression, *i. e.*, it will be equal to:

$$H = wV \operatorname{cosec} \varphi \quad \cos \varphi = wV \operatorname{cotan} \varphi. \qquad (4)$$

The "hoop tension" of this horizontal (radial) outward pressure will be found by dividing it by its circumference and multiplying by its radius ($r \sin \varphi$.). Hence the hoop tension, T, will be:

$$T = \frac{wV \operatorname{cotan} \varphi}{2\pi r \sin \varphi} r \sin \varphi = \frac{wV \operatorname{cotan} \varphi}{2\pi}. \qquad (5)$$

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As the crown of the dome is departed from, the weight constantly increases, but the inclination of the shell to a vertical line constantly decreases. Hence there will be some joint at which $wV\cot\varphi$, and, hence, T will become a maximum. That joint will be the so-called "joint of rupture," *i. e.*, the joint at which the outward, radial (horizontal) thrust is the greatest possible. Above this joint of rupture the dome will evidently be stable, for the reason that there will be no tendency to subject the masonry to anything but compression. At every ring joint below the joint of rupture, on the other hand, the outward radial thrust will be less than at the joint of rupture, and either the tensile resistance of the masonry ring between the joints, the supporting pressures of buttresses, or some other equivalent to those features must resist the difference in the outward pressures of the two joints or the difference of the corresponding hoop tensions.

If p_2 is the rate of change of hoop tension along the circumference $r\varphi$, *i. e.*, the change for each unit of length of $r\varphi$, then the joint of rupture will be located where $p_2 = 0$. If dT is the change in T for the indefinitely short distance $rd\varphi$, the change for the distance unity, which is p_2, will be:

$$p_2 = \frac{1}{rd\varphi} \cdot dT = \frac{dT}{rd\varphi} \tag{6}$$

By substituting the value of V from equation (2) in equation (5) there will result:

$$T = wr^2 [a(1 - \cos\varphi)\cot\varphi + cr(\sin\varphi - \varphi\cos\varphi)\cot\varphi] \tag{7}$$

Then if this value of T be placed in equation (6):

$$p_2 = \frac{dT}{rd\varphi} = wr\left[\frac{a(\cos\varphi - \sin^2\varphi)}{1 + \cos\varphi} + cr\left(\varphi\cos\varphi - \frac{1 - \varphi\cot\varphi}{\sin\varphi}\right)\right] \tag{8}$$

In order to locate the joint of rupture it will be necessary to place $p_2 = 0$ and solve the resulting equation for φ. It will be necessary to make the solution by trial which is quite practicable.

It is sometimes convenient to use the intensity p_y of the horizontal outward pressure whose total is H; *i. e.*, p_y is the horizontal outward pressure per unit of circumference corresponding to the

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hoop tension T. That intensity is found by dividing H, equation (4), by the circumference $2\pi r \sin \varphi$. After completing that operation there will result:

$$p_y = \frac{wV \operatorname{cotan} \varphi}{2\pi r \sin \varphi} = wr \operatorname{cotan} \varphi \left[\frac{a(1 - \cos \varphi)}{\sin \varphi} + cr(1 - \varphi \operatorname{cotan} \varphi)\right]. \quad (9)$$

In a complete hemispherical dome for which $\varphi = 90°$, P_1 by equation (3a) would become equal to the weight wV, while T and p_y would each be equal to 0.

If a circular opening is made at the top of the dome with a radius equal to $r \sin \varphi$, as shown in plan in Fig. 2, the expression for V will take the form:

$$V = 2\pi r^2 \int_{\phi_1}^{\phi_2} (a \sin \varphi \, d\varphi + cr \sin \varphi . \varphi . d\varphi) = \quad (10)$$

$$2\pi r^2 [a(\cos \varphi_1 - \cos \varphi_2) + cr(\sin \varphi_2 - \sin \varphi_1 + \varphi_1 \cos \varphi_1 - \varphi_2 \cos \varphi_2)]$$

In this case the angular coordinate φ_2 would locate any ring joint desired below the edge of the circular opening located by φ_1. The remaining equations would only be changed by taking V from equation (10) instead of equation (2). The position of the joint of rupture will obviously depend upon the angular width of the circular opening, as indicated by equation (8) in the new form which it would take.

The preceding equations are all that are necessary for the complete design of a spherical dome of uniformly varying thickness or for determining the stability of such a dome if already designed. They will be applied to the case of a brick dome (originally intended to be of concrete) which recently came under the examination of the writer. The thickness of the shell at the crown B, Fig. 3, was 0.75 ft., while at the springing joint it was 3.4 feet. The angular length of the center line from the crown was 63° 19′ = 1.105084 with units' radius. Hence by using equation (1), at joint A:

$$t = a + cr\varphi = 3.4 = 0.75 + 49 \times 1.105084 \times c$$
$$\therefore c = .04894.$$

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In this case the shell of the dome carried a 4″ shell or outer covering of stone besides a wind load taker as uniform at 50 pounds per sq. ft., so that those two loads were equivalent to about .8 ft. of additional concrete. No wind would ever produce a pressure of 50 pounds per sq. ft. over the surface of a dome, but it is quite impossible precisely to determine just what maximum pressure would exist or how it would be distributed. If, on the other hand, a uniform pressure of 50 pounds per sq. ft. be taken it may confidently be assumed that the wind loading is sufficiently recognized.

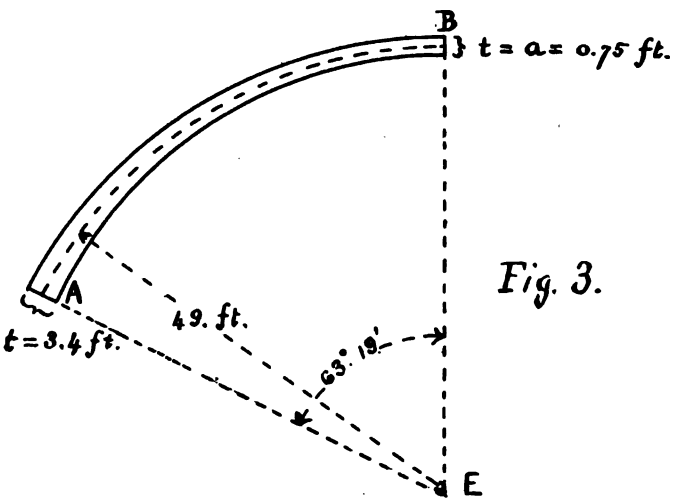

Fig. 3.

In consequence of these additional loads it will be necessary to take $a = .75 + .8 = 1.55$ ft. in the formulæ for pressures, hoop tension and joint of rupture. The latter joint will first be located. By placing the second member of equation (8) equal to zero and arranging terms:

$$\frac{a \cos \varphi}{1 + \cos \varphi} + cr\varphi\left(\cos \varphi + \frac{\operatorname{cotan} \varphi}{\sin \varphi}\right) = \frac{a \sin^2 \varphi}{1 + \cos \varphi} + \frac{cr}{\sin \varphi} \quad (11)$$

After a few trials it was found that by placing $\varphi = 59°$ in equation (11) the equation would stand:

$$3.5264 = 3.5478.$$

This result indicates that the point of rupture is a very little less than 59°, but so little less that 59° was taken.

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By the use of equation (7) the hoop tensions at the joint of rupture and at the springing joint are found as follows, the weight w per cubic foot of masonry being taken at 150 pounds:

At joint of rupture, $\varphi = 59°$:
$T = 334{,}866$ pounds.

At springing joint, $\varphi = 63° 19'$:
$T = 326{,}832$ pounds.

In this instance there were no buttresses to take up the horizontal thrust of the dome and, hence, steel rings or bands embedded in the masonry on the outside of the shell of the dome were employed. A low working stress should be taken for the steel or iron used in order to have a sufficient margin of resistance even should some corrosion take place. A working stress of 12,000 pounds per square inch was therefore taken for the steel rings. The net sectional area for the rings will then be:

$$\frac{334{,}866}{12{,}000} = 28 \text{ sq. in. (nearly).}$$

Two steel bands $12'' \times 1\frac{3}{8}''$ with the splice joints properly designed will give sufficient net section to meet the requirements. In this instance the joint of rupture is so near the springing joint that the two bands would be placed one immediately above the other, the upper one having a little less diameter than the lower to fit the varying slope of the outer surface of the dome.

In general, the first or highest metal ring or band would be placed at the joint of rupture and it should be of sufficient section to take up all the hoop tension between it and the next lower band. The latter should then be designed to take up all the hoop tension computed between it and the next lower one; and so on, until the springing joint is reached, where enough metal should be provided to resist all the hoop tension at that joint.

If buttresses are employed to resist the horizontal outward thrust of the dome, each buttress is to be treated as acted upon by its proportionate part of the total horizontal thrust taken as a horizontal force, the proportionate part of the weight of the dome as a vertical force and its own weight, all these forces being given their proper lines of action and points of application. The stability of the buttress will then readily be determined in the usual manner.

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There still remain to be found the unit loads on the masonry joints resulting from the inclined outward (tangential) thrust P_t given by equation ($3a$). That thrust is uniformly distributed over the entire ring joint. It is to be remembered that $w = 150$ lbs. *For joint of ruption*, $\varphi = 59°$; thickness of joint, $t = a + cr\varphi$ $= 0.75 + 49 \times 1.03 \times .0489 = 3\ 22$ ft. Radius of joint, $= r \sin \varphi$ $= 49 \times .85717 = 42$ ft. $\therefore$ area of joint $= 2\pi \times 42 \times 3.22 =$ 850 sq. ft.

By equation ($3a$) :

$$P_t = 4{,}109{,}000 \text{ pounds.}$$

Hence, pressure per sq. ft. of joint $= \frac{4{,}109{,}000}{850} = 4834$ lbs.

For springing joint $\varphi = 63°\ 19'$: thickness of joint, $t = a + cr\varphi =$ 3.4 ft. ; radius of joint $= r \sin \varphi = 43.8$ ft. $\therefore$ area or joint $=$ $2\pi \times 43.8 \times 3.4 = 935$ sq. ft.

By equation ($3a$):

$$P_t = 4{,}575{,}648 \text{ pounds.}$$

Hence, pressure per sq. ft. of joint $= \frac{4{,}575{,}648}{935} = 4{,}894$ lbs.

Both these unit loads are well within the safe working resistance of either brick masonry or concrete.

In the determination of P_t the crown thickness a has been taken at 1.55 feet, as already explained, while in the determination of the loads per sq. ft. of joints a is taken as 0.75 feet.

General Formulæ.

The general formulæ for a dome of any vertical section and of any thickness are written by Rankine and others as follows:

$$\text{Let } ds = d(r\varphi). \quad \text{Then } \frac{dy}{dx} = \operatorname{cotan} \varphi \text{ and } \frac{ds}{dx} = \operatorname{cosec} \varphi. \qquad (12)$$

If W is the weight of that portion of the dome above any joint located by φ, the total inclined tangential pressure at that joint will be: $P_t = W \operatorname{cosec} \varphi = W \frac{ds}{dx}$; and the total horizontal component of that tangential pressure or thrust will take the form:

$$H = W \operatorname{cotan} \varphi = W \frac{dy}{dx}. \qquad (13)$$

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The horizontal outward pressure per unit of the circumference $2\pi y$ has the value:

$$p_y = \frac{W \operatorname{cotan} \varphi}{2\pi y} = W \frac{\frac{dy}{dx}}{2\pi y}. \qquad (14)$$

The hoop tension T will then be:

$$T = y p_y = \frac{W \operatorname{cotan} \varphi}{2\pi} = \frac{W \frac{dy}{dx}}{2\pi}. \qquad (15)$$

Finally:

$$p_2 = \frac{dT}{ds} = \frac{1}{2\pi} \cdot \frac{d(W \operatorname{cotan} \varphi)}{ds} = \frac{1}{2\pi} \cdot \frac{d\left(W \frac{dy}{dx}\right)}{ds}. \qquad (16)$$

NOTES ON THE EXPLORATION OF MINERAL PROPERTIES.

By HENRY S. MUNROE.

Before the method of opening and working a mine can be planned intelligently, before the scale of operations can be definitely determined, and before the permanent plant is designed and erected, it is necessary to have as full and accurate information as possible as to the following:

1. The probable extent and area of the deposit, its average thickness, and the probable amount and value of the mineral to be obtained by mining operations.

2. The distribution of the workable areas of mineral in the deposit, that is the location and extent of their workable portions, and also of the barren or unworkable areas.

3. Conditions affecting the cost of opening, developing, and working the mine, or determining the methods to be adopted.

A deposit which is of small extent, or which is very thin, can as a rule be worked on a small scale only. The cost of mining per ton, will be large, and the ore must be rich, or the mineral valuable to be worked with profit. On the other hand a small and in-

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expensive plant, and a moderate amount of capital only will be needed.

A deposit of low grade ore, or of a cheap or abundant mineral must generally be worked on a large scale to yield a profit. To be workable the deposit must be of sufficient extent and of sufficient thickness to permit the necessary output to be obtained. Such a mine will generally require a large and expensive plant, and abundant capital for its successful operation.

Mining Risk.

It must be remembered that the line between a workable deposit and one that cannot profitably be worked is often very narrow; and further, that the majority of mineral deposits are not workable. The money that is spent in prospecting and in development is, therefore, liable to prove a loss. This is a recognized and legitimate business risk, differing only in degree from the risks attending all business operations. The risk of failure in mining enterprises is offset by the chances of more than ordinary profits. If the property proves valuable the returns may be very great.

While the risk of loss of capital is not to be avoided, the amount of the risk may be lessened by the exercise of prudence and caution.

It is of the utmost importance to limit the amount of money expended at first, while the extent and value of the deposit are still unknown and uncertain; and to do the necessary work at this stage of operations by the cheapest methods consistent with thoroughness. Any large expenditures, for plant or in costly method of exploration, will be unwise. As the work progresses, and the information as to the character and extent of the deposit becomes more definite and satisfactory, and as the prospects of success become more favorable, and the chances of failure diminish, money may be spent more freely.

The amount and kind of risk at the inception of a mining enterprise will vary with the character of the deposit. In the case of deposits of the cheaper and more abundant minerals, such as beds of coal and of iron ore, and in the case of large deposits of low grade ores, the extent and character of the deposit can generally be determined by surface examinations and at comparatively small expense. The risk of failure in such cases is chiefly that due to incompetent business management, or to the lack of sufficient capital.

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On the other hand in the case of less regular deposits, including most metalliferous veins and especially those of the precious metals, the uncertainty as to the continuance of the deposit is often very great and it is sometimes necessary to work the mine on a small scale for months, or even for a year or more, before the element of risk is so far reduced as to justify any considerable expenditure of money.

Work of Exploration.

The cheapest method of obtaining the necessary information above outlined is by surface explorations. The work of the prospector frequently furnishes much of the data required. By sinking additional pits or bore holes, by extending the costeaning ditches and uncovering the outcrop of the deposit more fully it is often possible to obtain all the information required for the most extensive and important mining operations. Whenever it is possible to do this the information gained is likely to be quite as accurate and conclusive as that to be obtained by underground workings. If the deposit shows great variations in thickness in its outcrop along the surface it is probable that a drift or a slope would show the same thing. If the workable areas are small and poor and appear only at long intervals along the outcrop, the chances of discovering larger, more numerous and richer areas by a shaft are infinitely small.

While the information obtained by surface explorations is always valuable and often conclusive as to the value of the deposit, it is usually necessary to supplement and confirm this data by underground work. As such work, the sinking of shafts or the driving of narrow entries or drifts is expensive, and as the mineral extracted rarely pays more than a small fraction of the cost of such workings, it is usual to plan this exploratory work so that the openings made shall serve some useful purpose later.

The mistake is often made, however, of undertaking for this reason the sinking of large and expensive shafts, or driving costly tunnels before it is fully proved that the deposit can be worked on a scale to warrant such developments, and indeed too often before it is known with certainty that the deposit can be worked at all! Any expenditure beyond that which is absolutely required to secure the necessary information simply increases the money risked, and in too many cases large amounts of money are thus unnecessarily lost by over confident and over sanguine mine managers.

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It is usually necessary to mine a few tons, or perhaps a few hundred tons of mineral to determine the richness or the economic value of the product by working tests. Such mineral, mined on a small scale, and with imperfect appliances is usually mined and treated at a loss; or, in the case of very rich ores, at a profit very much less than would be obtained in regular work. The loss incurred or the profits sacrificed are a legitimate part of the cost of exploring and developing the property, but these losses should not be made unnecessarily great by mining large amounts of ore before the mine is fully developed and the permanent plant erected.

The extent to which this work of exploration and development shall be pushed before the erection of the permanent plant will vary in each particular case and the decision of this question demands both experience and good judgment.

In the case of regular and uniform deposits, the continuance of which over large areas may be safely assumed, the amount of development is determined by the output desired and not by the necessity for exploration. In such case the openings need be extended only so far as to provide working places for the men required to produce the daily output, and the openings will be kept only so far in advance of the work of mining as may prove necessary to maintain this output.

In the case of irregular deposits, the continuance of which is more or less uncertain, and possibly containing large barren or unworkable areas, it may be necessary to continue the exploratory work until there is a certainty of a regular output for one or more years.

In very doubtful cases a conservative policy should be adopted and the mine should be worked at first on a very small scale and operations enlarged gradually and with caution as further developments are made.

It will thus be seen that the work of exploration may begin with and form a continuation of the surface prospecting and that it may continue through the period of opening and development.

In most cases, indeed, exploratory work continues through the whole life of the mine and forms a necessary or integral part of the regular mining operations. Even the most regular deposits have barren or low-grade areas, or are liable to "faults," "troubles" or "squeezes" in which the mineral is absent or unworkable, and it is important that the exploration should be far enough advanced at

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all times to ensure the development of new mineral areas before the exhaustion of the old.

The work of exploration should be under constant oversight. The data as obtained must be carefully studied that the full bearing of each new development may be recognized and the further work of exploration planned intelligently in the directions indicated by such developments.

The expenditures at each stage should be carefully limited to the risk warranted by the prospects of success.

On the other hand, the work of exploration should be thorough and complete.

1. The underground work should extend far enough in depth to prove the character of the unaltered deposit below the zone of surface action.

2. Exploration should be pushed far enough to determine the character and extent of the irregularities in thickness and in richness, and to obtain at least some idea of the location and distribution of the workable areas and their relations to the areas of barren and unworkable ground.

3. The number of openings made in the deposit including shafts, or drifts, will be determined by the nature of the problem in each case. In deposits of irregular and uncertain character the openings should not be so far apart as to permit large areas of barren or unworkable ground to escape detection.

4. If necessary, cross-cuts or bore-holes should be driven at intervals to search for and prove parallel beds or fissures, or to prove the deposit itself if wide or thick.

5. Assays should be made from time to time on carefully taken average samples, and these should be supplemented by working tests on lots of one ton or several tons representing fairly the average quality of the ore or mineral.

6. Finally the explorations and the work of development should be pushed far enough to make sure that there is sufficient mineral to warrant the erection of a permanent plant, and far enough to determine all questions affecting the profitableness of the enterprise.

In the case of a valuable deposit it is not unusual to spend $100,000 or more in this preliminary work of testing the value of the property. Indeed, equally large amounts are sometimes spent on perfectly worthless properties, owing to the lack of a proper pre-

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liminary examination and to the want of intelligent direction and oversight of the work.

In the case of rich properties it will sometimes happen that all or a large part of the expense of exploration will be paid from mineral extracted. In rare cases the necessary capital for the erection of a plant and for working has been thus secured.

In most instances, however, and especially in the case of the cheaper minerals or deposits of low grade ore, no profit can be anticipated until after the erection of a permanent plant and the commencement of regular operations on a large scale. In such cases the cash capital expended may reach $500,000 or $1,000,000, or even more. With such large interests at stake the exploration and development of such a mining property call for good business management and a high degree of technical skill and experience.

AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

By ALFRED J. MOSES, PH.D.

(Continued from page 422, Vol. XVIII.)

CHAPTER V.

MEASUREMENT OF CRYSTAL ANGLES.

The instruments used in measuring the angles between the faces of crystals are called *goniometers*, the simplest form being the application goniometer invented for Delisle by Carangeot and consisting of a semicircular graduated arc and two arms moving upon a pivot, the position of which may be changed according to the size and position of the crystal. In the older instruments the arms are fastened to the arc, but in the later types, as

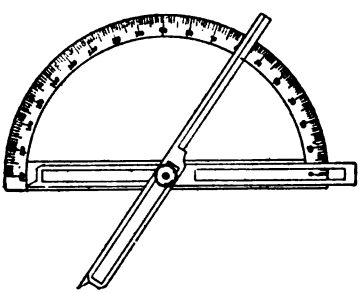

FIG 189.

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in Fig. 189, they are detached from the arc during measurement and replaced for the reading. In use the arms are each in close contact with a face and at right angles to the edge between the faces. They cannot be relied upon closer than one degree, and are, therefore, practically limited to the identification of previously measured angles.

All measurements of accuracy are obtained by rotating the crystal around the edge between the faces and determining, by the aid of a ray of light *fixed in direction*, the angle between the position in which the first face gives a reflection and that in which the second face does the same.

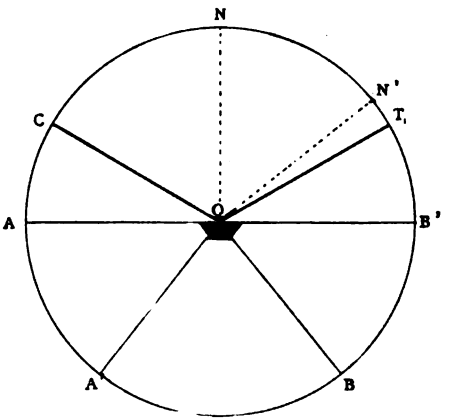

FIG. 190.

In Fig. 190 the crystal is so adjusted that an edge coincides with the axis of rotation *O*. The fixed direction of the ray of light is *CO*1 that is, the incident ray is *CO* and the eye or telescope is at *T*. Then *OA* will be the direction of the first face when it acts as a reflecting surface, and *OB* will be the direction of the second face at that time, and only when rotated to the respective directions, *OA'* and *OB'*, will a reflection be obtained from the second face, that is, after a rotation measured by the equal arcs *AA'*, *BB'* or *NN'*, the normal angle between the faces.

GONIOMETERS WITH HORIZONTAL AXES.

The original reflection goniometer is that of Wollaston.* In this a base and column support in a collar a hollow axle to which there is attached at one end a vertical disc with a graduated rim and at the other end a handle. Through this axle passes a second axle, with at one end the crystal holder and at the other a handle. These two axles may be clamped to turn together, or, by the inner axle, the crystal may be rotated without the graduated circle.

In the simplest forms of this goniometer the crystal is fastened

* W. H. Wollaston, Description of a reflective goniometer, *Phil. Trans.*, 1809, p. 253–259.

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with wax to a thin, flexible, brass plate, and this is fixed in a holder which has several simple motions by means of which the faces of the zone to be measured can be made to project clear of the apparatus and the edge to coincide with the axis of rotation. The signal may be a horizontal window bar twenty to thirty feet away, or better, a horizontal slit in a screen before an artificial light and it must be parallel to the axis of rotation. The eye is brought almost into contact with the crystal and there watches for the reflection of the signal as the faces successively move into position.

To secure a constant line of sight a reference mark may be made below the crystal parallel to the signal, or better, a second image of the signal may be obtained in a small mirror, the plane of which is parallel to the axis of rotation, or still better, a telescope with cross hairs may be used. In each case the rotation is continued until the image of the signal is bisected by or coincides with the reference mark.

Mallard's* modification of the Wollaston goniometer, shown in Fig. 191 on the left, differs from the earlier types in the sub-

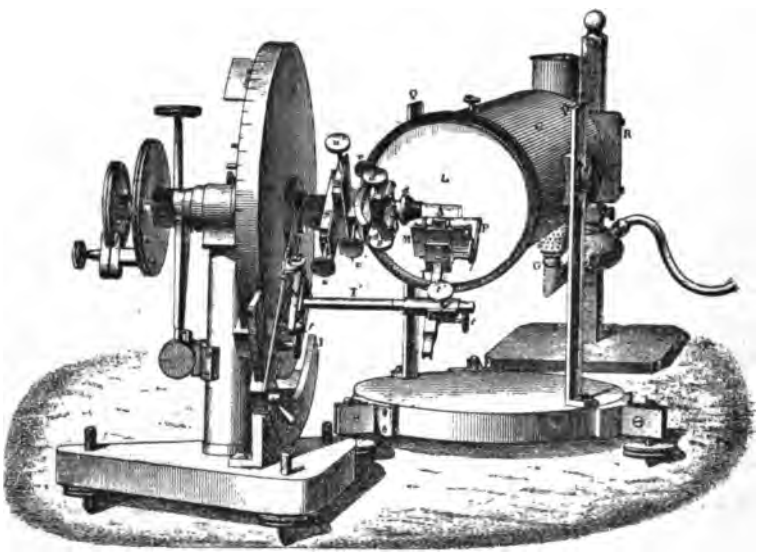

FIG. 191.

stitution of a better crystal holder; the crystal is supported in the manner suggested by Groth, that is, it is fixed with wax on a small

* Er. Mallard, *Annales des Mines*, Nov.-Dec. 1887.

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circular disc, d, and, by turning the screws v, v, and v', v', can receive two movements of rotation on two arcs of circles perpendicular to each other which have their common center near the middle of the crystal, A, so that the changes of orientation of the crystal do not too much displace its center of gravity.

For the proper centering, the entire system which holds the crystal is attached to two sliding planes, g and g', which, by means of the screws, u and u', impart to the crystal two movements of translation in a plane perpendicular to the axis of rotation. There is also a tangent screw for fine rotation and the mirror, M, has four motions of adjustment parallel to the axis of rotation. Any signal may be used, but preferably the collimator and artificial light, as shown in the figure.

The collimator is a cylinder, C, with at one end a large lens, L, and at the other, which is the exact focal plane of the lens, an adjustable plate, Fig. 192, pierced with signals, f, f', f'', of various

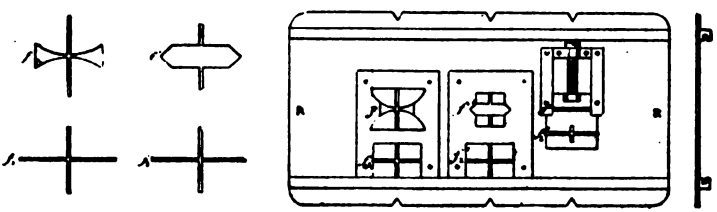

FIG. 192.

forms beneath each of which is a fine reference slit. The light from an Argand gas lamp, R, or a Welsbach burner passes through the central signals, emerges as *parallel rays* from the lens and is reflected to the eye at the same time from the crystal face and the mirror.

A greater degree of accuracy would be secured by the addition of an observation telescope, as in the Mitscherlich* modification of the Wollaston, but this is accompanied by loss of light and usually makes a dark room necessary, whereas the Mallard-Wollaston gives good results in ordinary light.

Professor Groth describes† a simple, inexpensive Wollaston with a telescope *fixed* parallel to the plane of the graduated circle and centered on the goniometer axis. The crystal holder is like that

* Ueber ein Goniometer *Abhandl. Berlin Akad.*, 1843, 189–197.

† *Physikalische Krystallographie*, III. Ed., p. 613.

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of the Mallard instrument, but the inner axle, which ordinarily rotates the crystal independently, is replaced by a screw which moves the crystal horizontally in the direction of the axis. The signal used by Professor Groth is a very small incandescent light at a distance of about thirty feet where it appears like a luminous point.

The principal objection to the Wollaston type of goniometer is that the weight of the crystal tends to throw it out of adjustment.

Goniometers with Vertical Axes.

Babinet, v. Lang, Miller, Websky and others have gradually developed this more perfect and more generally applicable variety of goniometer, and there is little doubt that for simplicity of adjustments and perfection of construction the instrument known as the Fuess Model II. at present excels all others. It is shown in Fig. 193 and consists of:

a. The Stand. A tripod with a conically bored head-piece supporting three concentric axles—*the outer axle* carrying the vernier circle and telescope, and turned by the latter; the fine adjustment is by the tangent screw, F, and the clamp screw, a,—*the middle axle* carrying the graduated circle and turned by the disc, g, or more conveniently by g';* the fine adjustment is by the tangent screw, G, and the clamp screw, β,—*the inner axle* guiding the rod of the crystal carrier and which may be turned separately or clamped to the others.

The circle is graduated to half degrees. The vernier circle is protected by a ring, K, with glass windows over the verniers, while between the tripod and the vernier circle is a ring with two arms each with a magnifier and a mirror, s, by means of which the vernier can be read to half minutes and estimated to quarter minutes.

a. The Crystal Carrier is like that described in the Mallard-Wollaston, the crystal being attached to a plate† by wax, and this to two *cylinder arcs*, which are moved by tangent screws around intersecting axes at right angles to each other and to the goniometer axis. The common point of intersection is within the crystal, so that

* The part g' is omitted in many instruments and the clamping of the inner axle is by a vertical screw.

† Two or three sizes are furnished. For very small crystals platinum wire may be used with a cement of gelatine and acetic acid. By bending the wire the different zones may be adjusted.

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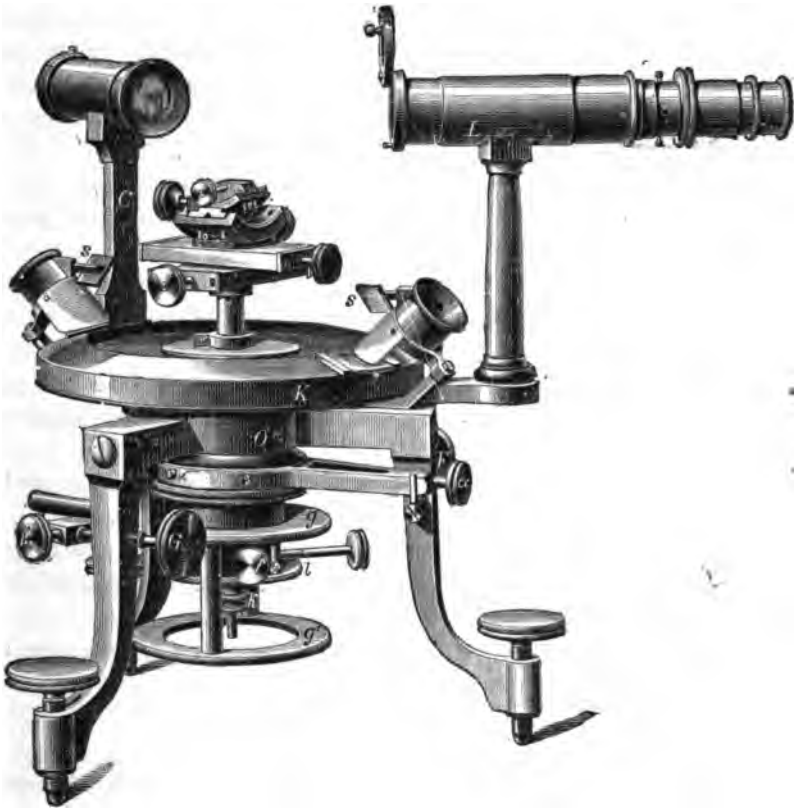

FIG. 193.

their motions tip the crystal without moving it much out of center. The arcs rest upon *sliding parts*, which are moved by micrometer screws, in the direction of the axes of the arcs.

c. THE TELESCOPE L. The observation telescope turns with the vernier circle to which it is attached by a pillar and its axis always intersects and is perpendicular to the axis of the goniometer. The vertical cross hair is parallel to the axis. Before the infinite distance objective swings an extra lens of a focal length equal to the distance to the goniometer axis. When in use this converts the telescope into a weak microscope. There are four eye pieces magnifying respectively six diameters, three diameters (generally used), two diameters (for distorted reflections) and a diminishing combination which is used with very small faces to reduce the signal to one third of its natural size.

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d. The COLLIMATOR. The infinite distance collimator is *fixed* firmly to the tripod by the pillar *C* and its axis and the telescope axis are in the same place perpendicular to the goniometer axis. The signals are either separate tubes or all four may be on a revolving target in the focal plane of the collimator lens.

The *Schrauf signal* is a light diagonal cross on a dark back ground, with, at the center, very minute cross hairs which are used in the adjustments and with rare very perfect faces.

The Websky Signal is an orifice bounded by two circular discs of equal diameter, the distance apart of which is regulated by a screw. This admits more light than a narrow cleft while still very narrow in the center and if dilated by a narrow face (see p. 23) and diminished in intensity the shape may still be divided symmetrically with some accuracy.

The Slit Signal is an adjustable vertical cleft especially adapted to broad faces or for measurement of indices of refraction.

The Pinhole Signal is a round ½mm. opening used in adjusting and in recognizing slight deviations from the zone or, by multiple reflection, cracked and facetted faces.

After the instrument is in adjustment* once for all the process of measurement is as follows:

---

*The complete adjustments are:

1. *Adjustment of the vertical hair.*

A needle is adjusted in the axis of the goniometer, so that during rotation it does not appear to move.

An eyepiece is adjusted so that its cross hairs are distinct and is then placed in the telescope tube, focussed on some distant object, the extra lens dropped into position and the eyepiece turned until one hair is parallel to the needle, then the cross hairs are moved horizontally until this hair coincides with the needle.

Making Telesccope axis normal to Goniometer axis.

A plate of parallel glass is fastened to the holder approximately parallel to the goniometer axis and perpendicular to the telescope axis and is made exactly so by reflecting light upon the cross hairs from another plate fastened in front of the eyepiece at about 45° to the telescope axis. The reflected light throws an image of the cross hairs upon the parallel glass, which is reflected back into the telescope.

By aid of the arcs the images reflected from opposite sides of the parallel glass are made to take the same position in the field, that is, the plate is made exactly parallel to the axis of the goniometer, and by raising or lowering the cross wires their center is brought into coincidence with its image as seen after reflection. The telescope axis is then normal to the plate and therefore to the axis of the goniometer.

Adjustment of Horizontal Hair.

During rotation of the outer axle the image of the intersection of the cross wires should move across the field in coincidence with the horizontal wire, if not, raise, lower, or turn the wire as needed.

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Several of the smallest and most brilliant crystals are selected, carefully cleaned with chamois skin and thereafter handled only with pincers or a tapering pencil of wax. Sketches are made showing striations, flaws and other peculiarities as revealed by the magnifier and later by the micro-telescope. Letters are assigned to all faces and thereafter represent them.

The most prominent zone is first measured and is designated by the letters of its two most prominent faces, say [*A C*]. The crystal is fastened with a conical pencil of wax to the plate so that the zone axis is approximately vertical and one face is parallel to one of the motions of translation.

The crystal is brought into view by the extra lens and raised or lowered by the mother screw *k*. With one arc at right angles to the telescope axis one of the edges of the zone is made coincident with the vertical hair by means of the corresponding micrometer screws; then with the other arc at right angles to the telescope axis the same adjustment is made with the other screws, and this is repeated until during a rotation the edge and vertical hair appear to be one, and on raising the extra lens the image of the signal from any face in the zone is symmetrically bisected by the cross hairs.

Except in the case of very narrow faces* it is not necessary to recenter on each edge, but is sufficient by a slight motion with the centering screws to make the vertical hair coincident with an imaginary central axis within the zone.

With the telescope at some convenient angle to the collimator (100 to 120 degrees) and with only β unclamped, the graduated circle and crystal are turned together by the disc *g* until the reflected signal is seen through the telescope, then β is tightened, the signal moved by the tangent screw *G* until it is bisected by the vertical cross hair and the vernier is read and recorded.

The Collimator Adjustment.

The pin hole signal is first inserted, focussed, and its center made to coincide with the horizontal wire of the telescope by the screw which fastens the pillar *C* to the tripod. The vertical slit and Websky's signal are focussed and made symmetrical to the telescope cross hairs and finally the cross hairs of the Schrauf signal are brought into apparent coincidence by their traversing screws.

The Other Eyepieces.

Are adjusted by means of Schrauf's signal. All eyepieces and signals have sliding collars with a projecting tooth which fits into a notch in the tube of the telescope or collimator. The collar is tightened when the tube is in final adjustment and thereafter is fixed. (M. Websky, *Zeit. f. Krystallographie*, IV., 545.)

* See page 23.

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The screw β is again loosened and the rotation continued until the signal is received from a second face, and this is centered by G and β and recorded as before and the difference between the two readings is the normal angle. The position of a third face is determined in the same way and so on around the zone.

At least three measurements of any angle should be made and preferably with different portions of the circle. For the second measurement when the signal from the second face is centered the clamp l is loosened and the crystal alone is turned until the signal from the first face is centered, then l is tightened and β loosened and the crystal and circle turned together as before. This is repeated before a third measurement.

It is important to assign a quality mark to each image of the signal. For instance, a distinct image may be 2, a poor image 1, a band or shimmer 0, and the proportionate value of any measurement may then be taken as the sum of the quality marks of the readings. These may be recorded in tabular shape, as in the following example:

CRYSTAL 1. Zone [m m'''']

Face.	Quality.	Readings. First.		Second.		Third.		Mean Normal Angle.		Times to be counted.
		°	′	°	′	°	′		° ′	
m	1	137	24½	54	53½	332	21	mm'	82 31½	1 + 2 — 3
m'	2	54	53	332	21½	249	50	$m'a'$	48 45½	2 + 2 — 4
a'	2	6	6½	283	36	201	5	$a'm''$	48 44½	2 + 1 — 3
m''	1	317	23½	234	51	152	20½	$m''m'''$	82 28½	1 + 2 — 3
m'''	2	334	56	152	22	69	50½	$m'''a$	48 44½	0 + 2 — 2
a	0	867	11	103	38½	21	6	am	48 45½	0 + 1 — 1
m	1	112	24	54	53½	332	21			

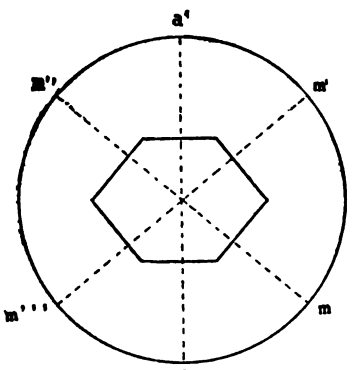

FIG. 194.

The angles indicate that m, m', m'', m''' are faces of one form and that a, a' are faces of another form truncating the first as in Fig. 194. The most probable angles will be determined by averaging. For instance, the probable angle m–m''' may be the average of:

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	° ′	Times to be counted.	Minutes.
* $2\,m\,a$	$= 97\ 30\frac{1}{2}$	$\frac{1}{2}$ or 1	$30\frac{1}{2}$
$2\,m'''\,a$	$= 97\ 28\frac{1}{2}$	1 " 2	$57\frac{1}{2}$
$2\,m'\,a'$	$= 97\ 31\frac{1}{2}$	2 " 4	$125\frac{1}{2}$
$2\,m'''\,a'$	$= 97\ 28\frac{1}{2}$	$1\frac{1}{2}$ " 3	85
$180 - m\,m'$	$= 97\ 28\frac{1}{2}$	3 " 6	171
$180 - m''m'''$	$= 97\ 31\frac{1}{2}$	3 " 6	187
$m\,m'''$	$= 97\ 29\frac{1}{2}$	3 " 6	177
$m'\,m''$	$= 97\ 29\frac{3}{4}$	3 " 6	179
		34	1012

$$m - m''' = 97^\circ\ 29\tfrac{3}{4}'$$

ERRORS DUE TO IMPERFECT CENTERING.

Let E denote the error.

Let a denote the angle between the crystal edge and the goniometer axis.

Let γ denote the angle obtained.

Then will $E = \frac{a^2}{2\sqrt{2}}\,[\cos 45^\circ - \cos(2\gamma + 45^\circ)]$.

This value is a maximum when $\cos(2\gamma + 45^\circ)$ is -1, that is, when $\gamma = 67\frac{1}{2}^\circ$ for which $E = \frac{6}{10}\,a^2$ (approximately) and a minimum when $\cos(2\gamma + 45^\circ) = +1$ or $\gamma = 157\frac{1}{2}$ for which $E = \frac{1}{10}\,a^2$.

This error is guarded against by the coincidence of signals from different faces of the zone.

In addition.

Let i denote angle of incidence of the light.

Let d and d'' denote the distances of the faces from the axis.

Let r denote the distance to the light source.

Then will $E = \frac{d - d''}{r} \sin i$.

This diminishes as r increases or i decreases and is zero if r is infinite or $d = d''$; that is, the second error is eliminated by an infinite distance collimator, and even without it is only about 9″ if $d - d'' = \frac{1}{2}$ mm. and $r = 10$ m.

SPECIAL CASES IN MEASUREMENT.

Narrow faces tend to broaden the image by a phenomenon analogous to diffraction. The diminishing eyepiece may obviate this, but as the error is proportionate‖ to the eccentricity of the face, in such a case each edge must be separately centered.

* The errors in the first four are already doubled, hence they can be allotted only half the sum of their quality marks.

† Story Maskelyne's *Crystallography*, p. 414.

‡ Ibid, 402.

§ For other reasons i is commonly 50° to 60°.

‖ *Bull. Soc. Min. de France*, I., 35.

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Transparent Crystals give colored images due to total reflections within the crystal, if the crystal and telescope are turned steadily in one direction these images at a point move backwards (angle of least deviation); when such an image coincides with the true one it is only necessary to alter the angle of incidence.

Finely Striated Faces yield a bright colorless image with colored images on each side. The bright image is due to the plane tangent at the edges of the striæ and only when an image is obtained after the plane has been turned into some other zone is it proved that there is a definite crystal face underneath the striæ.

Bent or Cracked Faces yield distorted or manifold images. An irisblende eyepiece will limit the reflection to a selected best portion, or an approximate measurement may be obtained from the outer member of each group, or by measuring in several zones to the opposite face the properly oriented portion may be found. The best way is to use another crystal.

Twin Crystals and Composite Crystals in approximately parallel position will give good images in part of a zone and in the rest the images will be a little out of center.

*Dull Faces** may be coated with thin varnish or cover glasses may be glued to them or the extra lens may be used, the collimator slit narrowed to the smallest width which will give an illumination and the position of BRIGHTEST ILLUMINATION of both faces recorded several times. Traube's attachment to the collimator of the Fuess goniometer† shown in Fig. 195 may be used. It is

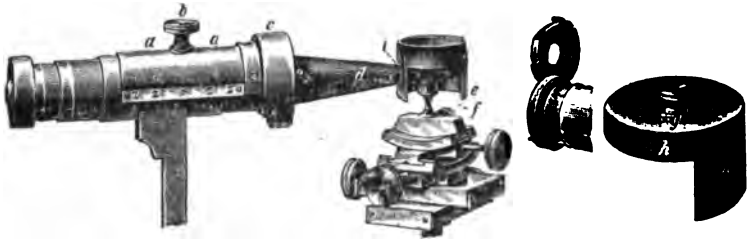

FIG. 195.

practically a little extra dark room; the light passing through the collimator and the conical tube *d* to the crystal. The cylinder *e*

*Groth describes an elaborate application gomometer "das Fühlhebel goniometer" for measuring dull crystals *Physikalische Krystal.*, III. Ed., pp. 604–608.

†*Neus Jahrb. f. Mineralogie*, 1894, Bd. II.

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shuts out much of the extraneous light giving a darker field in which the luminous signal is by contrast brighter. Still more light can be shut out by laying a card over the top of *e* or better by the cap *g*, which may be turned to diminish the window *f* to a mere slit.

Small and nearly parallel faces which yield a combined image may be distinguished by changing the angle of incidence.

Crystals which alter in the air may be protected during measurement by replacing the crystal plate by a hollow cylinder* *a*, Fig 196, supporting a hemisphere *s* and plate *t*, the whole cov-

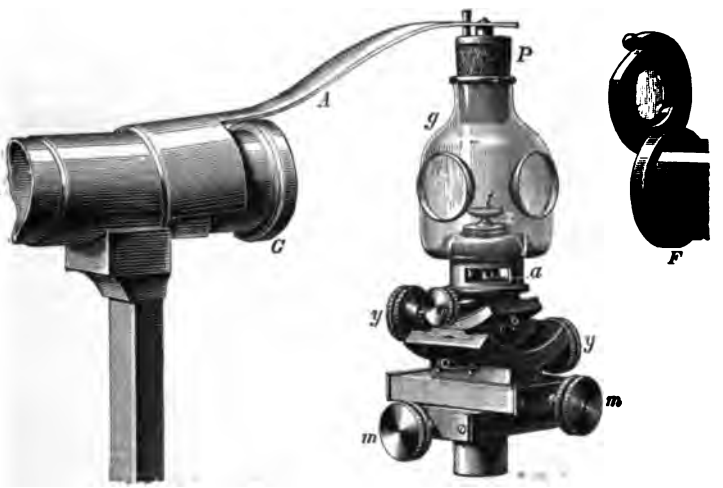

FIG. 196.

ered by a little glass bottle with bottom pressed in and ground to fit air-tight in the oiled hemisphere. In the channeled bottom is placed sulphuric acid or chloride of lime for deliquescent crystals, and water, etc., for efflorecent crystals. The bottle is steadied by the spring clamp *A*, and the light enters and emerges normal to the plane windows of the bottle.

Imbedded crystals may be measured to within one degree by means of impressions in sealing wax.

THEODOLITE OR TWO-CIRCLE GONIOMETERS.

In the reflection goniometers described all faces of the zone which is placed perpendicular to the graduated circle reflect the signal and

* *Jahrb. d. geol. Reichsanstalt*, 1884, 329.

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if the circle is considered to be the plane of projection their poles are in the circumference at angles apart equal to those measuring the rotation.

If a second direction of rotation at right angles to the other be added, *any* face in *any* zone may be referred to this first zone by the two motions necessary to bring it into the field, the one giving the point where its meridian cuts the primitive circle, the other giving the number of degrees on this meridian from the primitive circle. Czapski, Goldschmidt* and v. Federow have described such instruments; that of the latter, shown in Fig. 197, consists of a telescope

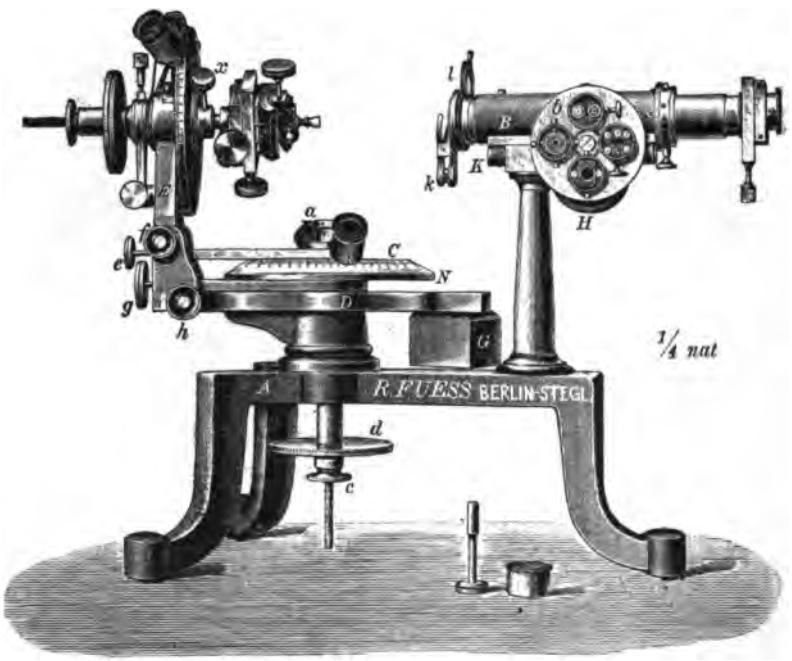

FIG. 197.

B, which is also the collimator. The signals are on the revolving disc *b*, and the light entering at the focal plane of the objective passes through a small total reflecting prism and emerges as parallel rays. There is an extra lens *l* to bring the crystal into focus or, by means of the spring clamp *h* and the rack and pinion *H* and *K*, one of the weaker objectives of a microscope may be focussed on the crystal. The eye-piece has an adjustable irisblende.

* *Zeit. f. Kryst.* XXI., 210–232.

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The stand consists of a tripod with a bored conical head in which rests the graduated circle *C* turned by *d* and read by the fixed vernier *N*, using clamp *e* and tangent screw *f*. The stand also supports *D*, the carrier of the vertical circle, which can be clamped to the stative by *g*, or to the horizontal circle by *e*.

The vertical circle is a complete Wollaston goniometer, but rotates with the horizontal circle when *e* is clamped. By transferring the centering apparatus to the horizontal circle the instrument may be used as a goniometer with vertical axis.

CHAPTER VI.

CRYSTAL PROJECTION OR DRAWING.

For the purposes of calculation and for a comprehensive view of the relations between the faces, the latter are more conveniently represented either by points, Fig. 198, as described pp. 284–288, under stereographic projections, or by lines as in the so-called Linear projection. For description and illustration some projection which actually figures the shape of the crystal is usually preferred.

Linear Projections.

In Quenstedt's linear projection* each face of the crystal is assumed to be moved parallel to itself until it cuts the vertical axis at a unit's distance above the the plane of the basal axes. The line in which the face then intersects the plane of the basal axes represents the plane.

For example, the crystal of topaz, Fig. 201, is orthorhombic in crystallization with $a : b : c = .529 : 1 : .477$. The basal axes are drawn at right angles, and the proportionate lengths .529 : 1 laid off upon them. As the crystal is symmetrical to the axial planes it is only necessary to determine the projections of the faces of one octant, say the upper right hand. The indices of these, therefore, are written, then their reciprocals, which are the axial intercepts (p. 277), and finally, these divided by the third term, that is, the intercepts of the faces when they cut the vertical axis at unity—

* *Beiträgen zur rechnenden Krystallographie*, Tübingen, 1848.

† In Goldschmidt's Euthygraphic Projection the faces cut a unit's distance below the basal axes. *Ueber Projection u. graph. Krystal.*, p. 25.

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Indices.	Reciprocals.	Unit *c* intercepts.
111	111	111
110	11∞	001
120	1$\frac{1}{2}$0	001*
223	$\frac{1}{2}\frac{1}{2}\frac{1}{3}$	$\frac{3}{2}\frac{3}{2}$1
041	$\infty\frac{1}{4}$1	$\infty\frac{1}{4}$1

The points on *a* and *b* corresponding to the first and second term of each unit *c* intercept, are then connected by a straight line which is the linear projection of the face. Fig. 200.

The projection of the edge between any two faces is evidently the line from the center of the projection to the intersection of the two lines representing the faces, and the direction of that edge is the line from the intersection to the unit point on the vertical axis. Hence all faces projected in lines with a common intersection intersect in parallel edges or lie in one zone. Evidently also a face lying in two zones will be projected in the line through the two common intersections or zonal points.

The zonal equations may be here used as described, pp. 280–283, and calculations may be made, though less conveniently than with the stereographic projection.

Projections in Parallel Perspective.

If the eye be conceived to be at an infinite distance the visual rays become parallel, and all parallel lines remain so † when projected, and the *proportionate* lengths into which any line is divided are not changed, although the line may be foreshortened.

Orthographic Parallel Perspective.

The plane of projection is at right angles to the visual rays. If the plane is the base the basal axes are full length, but if it is at right angles to the vertical axis the axis *a* in monoclinic crystals will be foreshortened to *a* sin β and in triclinic crystals *a* will become *a* sin β and *b* will become *b* sin α.

The faces of the zone normal to the plane of projection will be projected as lines bounding the figure at their true angles. The edges between other faces will be parallel both to the *edge projections* (see above) of the linear projection on the same plane or to

* Prisms are all projected as lines through the center *parallel to the projections of pyramids* of the same zone. In this case such a pyramid as 121.

† Lines parallel in projection are not necessarily so in the crystal, for all lines in a plane through two rays are projected in the same line.

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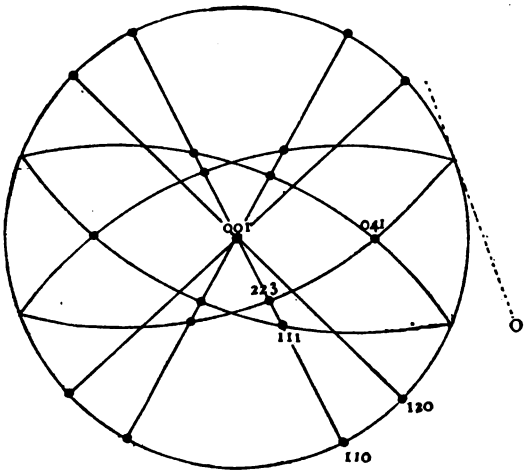

FIG. 198.

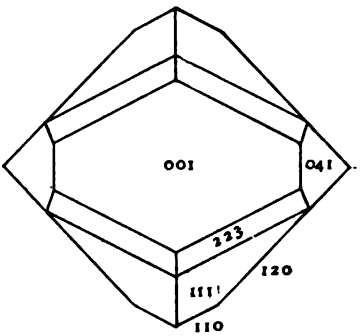

FIG. 199.

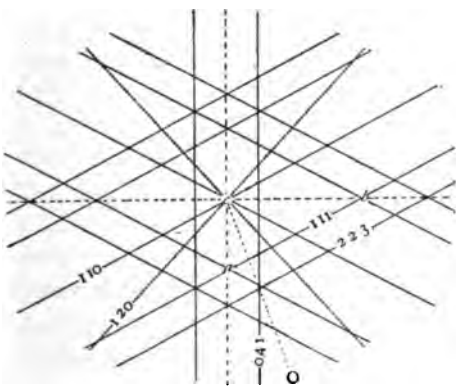

FIG. 200.

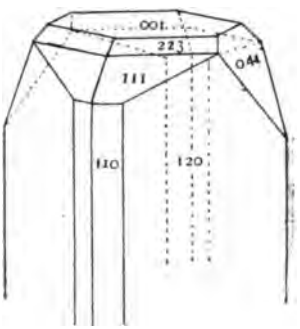

FIG. 201.

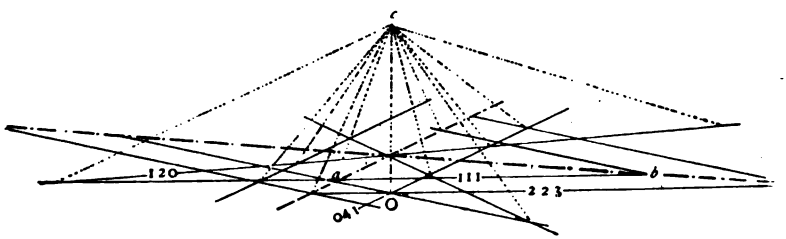

FIG. 202.

PROJECTIONS OF A TOPAZ CRYSTAL.

198. Stereographic.
199. Orthographic Parallel.
200. Linear.
201. Clinographic Parallel.
202. Linear upon axial cross.

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the tangent to the primitive circle at the intersection with the zone circle of the two faces. For instance, in Fig. 199, the direction of the orthographic projection of any edge, say [041, 223], is both that of the line *Oc*, Fig. 201, and of the tangent at *O*, Fig. 198.

Clinographic Parallel Perspective.

The plane of projection is oblique to the visual rays. This method gives an appearance of solidity and usually is made upon a vertical plane, the point of sight being to the right and above the crystal.

The Axial Cross, or perspective view of the axes, is first prepared.

If the angle to the right, or horizontal angle, is denoted by δ and the angle of elevation by ϵ, then the following relations* exist between these angles and the projected lengths and angles of the isometric axes in which the notation is as in Fig. 203.

$$OA = \sqrt{1 - \cos^2\delta\cos^2\epsilon}\,;\quad OB = \sqrt{1 - \sin^2\delta\cos^2\epsilon}\,;\quad OC = \cos\epsilon$$

$$\cot AOC = -\delta\sin\epsilon\,;\quad \cot BOC = -\tan\delta\sin\epsilon\,;\quad \cot\delta = \sqrt{\frac{\cot AOC}{\cot BOC}}$$

$$\cos AOC = -\frac{\sqrt{(OA^2 + OB^2 - OC^2)\,(OB^2 + OC^2 - OA^2)}}{2\,OA.OC};$$

$$\cos BOC = -\frac{\sqrt{(OA^2 + OC^2 - OB^2)\,(OA^2 + OB^2 - OC^2)}}{2\,OB.OC};$$

The following table gives a series of projections, of which numbers 3, 4, 5, 6 and 10 are usually preferred.

Number.	Angles of Revolution.		Angles between projected Axes.		Foreshortened lengths of axes for true length = 1.			Approximate Proportionate lengths.		
	δ	ϵ	AOC	BOC	OA	OB	OC	OA	OB	OC
1	11° 35′	0° 49′	93° 58′	90° 10′	.200	.980	.999	10	49	50
2	14° 35′	1° 17′	94° 55′	90° 20′	.250	.968	.999	8	31	32
3	18° 26′	6° 20′	108° 19′	92° 06′	.239	.828	.994	29	100	120
4	18° 26′	7° 11′	110° 34′	92° 23′	.338	.950	.992	36	100	105
5	18° 26′	9° 28′	116° 17′	93° 8′	.353	.950	.986	37	100	104
6	19° 16′	2° 14′	96° 23′	90° 47′	.333	.944	.998	6	17	18
7	27° 59′	9° 50′	107° 49′	95° 11′	.493	.887	.985	5	9	10
8	45°	35° 16′	120°	120°	.817	.817	.817	1	1	1
9	20° 42′	19° 28′	131° 25′	97° 11′	.471	.943	.943	1	2	2
10	13° 38′	13° 15′	133° 24′	93° 11′	.324	.973	.973	1	3	3
11	10° 10′	10°	134° 6′	91° 47′	.246	.985	.985	1	4	4

* Story-Maskelyne's *Crystallography*, p. 480. Jos. Barrett, *Lehigh Quarterly*.

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In drawing the cross, OC is vertical and the directions of OA and OB result from the angles AOC and BOC. The proportionate lengths may be laid off at any scale desired.

When cot δ and cot ϵ are simple numbers as in Nos. 3 and 5 in which cot $\delta = 3$ and cot $\epsilon = 9$ and 6 respectively, the projection of the axial cross may be obtained as follows:

A horizontal line ss, Fig. 203, is bisected by a perpendicular, and perpendiculars are drawn as indicated at the ends and at points t and t' and distances laid off so that

$$Ot = Ot' = sg = \frac{Os}{\cot \delta} \text{ and } s'\epsilon = Os \frac{\cot \delta}{\cot \epsilon}$$

(in the figure cot $\delta = 3$, cot $\epsilon = 6$).

The point e determines the line eO and AA'; the projection of the front horizontal axis is the portion of this line which is included between the perpendiculars at t and t'. The point g determines the radius Og, which is the length of half the vertical axis CC'. For the projection of the third axis draw Af parallel to ss', draw fO, and from the intersection v draw vB parallel to ss'. BB' completes the desired projection or axial cross.

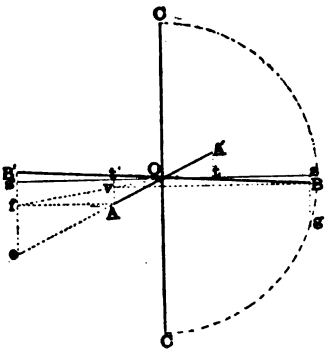

FIG. 203.

The axial cross for crystals of other systems is derived from the isometric cross by assuming the latter to be the projection of lines each equal in length to that axis of the crystal which extends conventionally from left to right (b).

In the TETRAGONAL and ORTHORHOMBIC crosses the proportionate values of the axes c and a are laid off on CC' and AA' respectively. In Zircon, for instance, the vertical axis is made $\frac{64}{100}$ of CC'.

In the MONOCLINIC crosses, Fig. 204, the vertical axis is a proportionate length on $C\overline{C}$, but $A\overline{A}$ is the projection of a line at right angles to $C\overline{C}$ and the *direction* of the clino axis is first found by laying off $Or = OC \cos \beta$ and $On = OA \sin \beta$ and completing the parallelogram $OAtr$. The proportionate value of a is then laid off upon the diagonal Ot.

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This and other projections are quickly obtained by using a metal quadrant.* Fig. 204 the center of which is at B. The edge AB and the arc AC are tapered to a thin edge for greater exactness in marking. With AB ten centimeters long the results will be correct within the limits of a drawing.

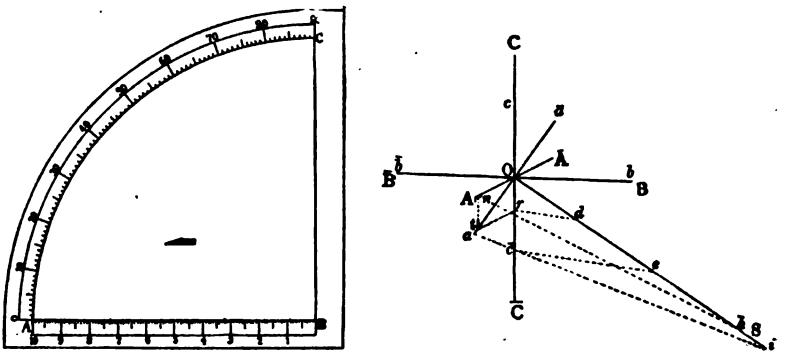

FIG. 204.

A scale line OS is drawn at will from the center O and axial lengths are transferred directly from AB to the scale line approximately to the third decimal. Sines and cosines are transferred as follows. If the edge BC and the scale line are made coincident and then, by use of a triangle, the quadrant is slid along in a direction at right angles thereto (BC remaining parallel to the scale line) until the scale line cuts the arc at the given degree and the approximate minute, the intercept on the scale line will be the sine. Similarly with the edge AB coincident with the scale line and a motion at right angles thereto, the intercept on the scale line will be the cosine.

All measurements are transferred to other lines, by lines parallel to the direction between the ends of the scale line and the unit line. For instance, in a monoclinic crystal in which $a:b:c=1.092:1:0.589$ and $\beta=74°\ 10'$. Oh is sine $74°\ 10'$ when radius is OS and transferred to OA is On; Od is cosine $74°\ 10'$ when radius is OS and transferred to OC is Or; by completing the parallelogram t and Ot result. For the axial lengths, Oi is 1.092 times OS and Oe is 0.589 times OS and transferred are respectively $Oa=1.092\times Ot$ and $Oc=0.589\times OC$.

* Described A. J. Moses, *Am. Journ. Science*, I., June, 1896.

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In the *triclinic* crosses, Fig. 205, the same method is carried further, for instance: The constants for axinite are $a:b:c=0.492:1:0.479$, $a \wedge c=\beta=91° 52'$, $b \wedge c=a=82\ 54'$ $(100) \wedge (010)=131° 39'$.

Vertical Axis. Make $Oc=OC \times .479$.

Macro Axis. Make $Oe=OB \sin 131° 39'$, and $Od=OA \cos 131° 39'$; complete the parallelogram *dOen*. Make $Or=On \sin 82° 54'$ and $Ox=OC \cos 82° 54'$; complete the parallelogram *rOxb*. Then is *Ob* the projection of one-half the desired axis.

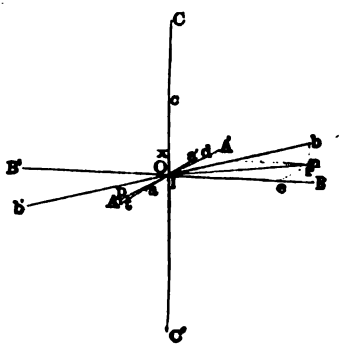

FIG. 205.

Brachy Axis. Make $Ol=OC \cos 91° 52'$, and $Op=OA \sin 91° 52'$. Complete the parallelogram; *pOlt* make $Oa=0.492=Ot$; then is *Oa* the projection of one-half the desired axis. These results are more quickly made with the quadrant previously described.

In the HEXAGONAL CROSSES, Fig. 206, the proportionate value of *c* is laid off on *CC'* and the basal axes are derived as follows:

Make $Op=OA=1.732$; draw *pB* and *pB'*; bisect *Op* by a line parallel to *BB'*; then are *OB*, *Oa* and Oa_3 the projections of desired semi-axes.

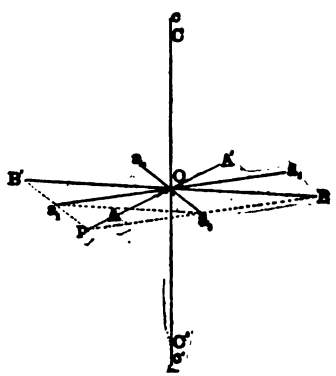

FIG. 206.

DETERMINATION OF THE DIRECTION OF EDGES.

The unit form always results from joining the extremities of the axial cross by straight lines and other simple forms are easily drawn by methods which suggest themselves, for instance, the unit prism by lines through the terminations of the basal axes parallel to the vertical axis. It is always possible, also, to obtain two points of any edge by actually constructing the two planes and finding the intersection of their traces in two axial planes. The method, however, is cumbersome.

In all systems the projected intersection may be most easily found by the following method: A linear projection of the faces

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is made (Fig. 202) upon the basal axes of the axial cross precisely as described for the ordinary linear projection. One point of the edge between any two planes is the unit point on the vertical axis; another is the intersection of the linear projections of the two planes and the line connecting these is the edge. For instance, *Oc*, Fig. 202, is the direction of the edge [041, 223] and is so drawn in Fig. 201.

CONSTRUCTION OF THE FIGURE.

The edges thus formed must be united in ideal symmetry, yet so as to show, as far as possible, the relative development of the forms.

A second axial cross is drawn parallel to that used in determining the edge directions and these are transferred by triangles, care being taken that all corresponding dimensions are in their proper proportions and in accord with the planes of symmetry. Generally it will be best to pencil in and verify the principal forms and later work in the minor modifying planes.

The back (or dotted) half of many crystals can be obtained by marking the angles of the front half on tracing paper, turning the paper in its own plane 180° and pricking through. This is also a test of accuracy, for the outer edge angle for angle should coincide.

TWIN CRYSTALS.

These have two set of axes, the second so related to the first that it corresponds to a revolution of 180° about the twin axis or line normal to the twining plane.

The two individuals may be in *apposition*, that is, the twin plane coinciding with the combination face. In this case the twin axis which passes through both centers normal to the twin plane will be bisected by the latter.

In interpenetrating twins the two centers may coincide or be near together. The orientation, however, will be as in the former case.

*Given the axial cross of one crystal to find that of a second crystal in apposition thereto.**

Let *OA OB OC*, Fig. 207, be the axial cross of the first crystal and *HKL* the twinning plane. To find first the point *Z* at which the normal from *O* cuts *HKL*, draw *H'L* and *HL'* parallel *AC* and draw *KL''* and *K'L* parallel *BC*. Complete the parallelograms

* Groth, *Physikalisoche Krystallographie*, p 599, III Ed.

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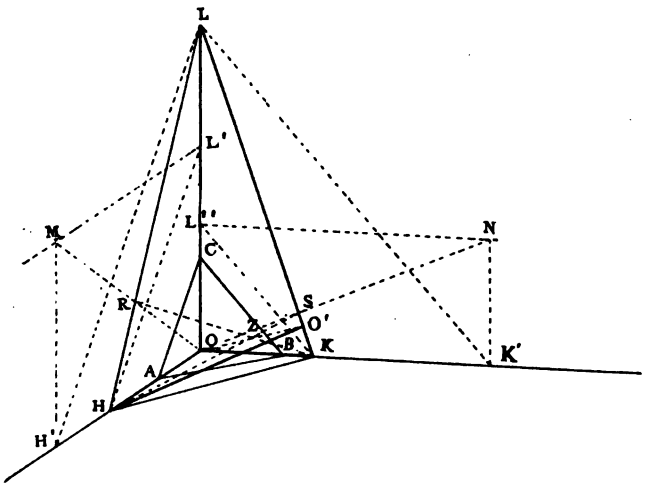

FIG. 207.

OH'ML' and *OK'NL''* and draw their diagonals *OM* and *ON* and from the intersections of these with *HL* and *LK* draw *RK* and *SH* respectively; their intersection is the desired point *Z*.

Because the crystals are in apposition prolong *OZ* till $ZO' = OZ$, then is *O* the center of axes for the second crystal and as the face *HKL* is common *O'H*, *O'K* and *O'L* are in direction and length the coordinates of this face on the new axes.

The unit lengths will be found by drawing *AA'*, *BB'* and *CC'* parallel to *O'Z*.

All constructions on the axes of the second crystal follow the rules previously given.

NOTES ON THE PRESENT WESTERN PRACTICE OF METALLURGY—ECONOMICALLY CONSIDERED.

PART II.

BY W. B. DEVEREUX.

Copper metallurgy in the West may have for its object:

I. The extraction of copper from ores which do not contain any appreciable amounts of precious metals.

II. The treatment of ores which contain, in addition to the copper, an appreciable amount of precious metals.

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III. The treatment of an ore mixture consisting of copper ores and so-called dry ores, the latter term being used to denote ores which contain precious metals, but no appreciable amount of either copper or lead, as the case may be.

Under the conditions existing in a smelting furnace copper has a great affinity for both gold and silver, and a very small percentage of copper will suffice, in a good smelting mixture, to extract a large percentage of the precious metals contained. Under some conditions, as low as 2½ per cent. of copper in the total charge is found to produce good commercial results. With very few exceptions smelting processes are used to extract the copper from ores or ore-mixtures.

I shall not attempt in these lectures to do more than outline the processes which are most in vogue at present, and indicate the general tendencies which show the direction in which progress is being made.

So far as operations in the West are concerned, the smelting of the ore-mixtures is the principal process, and this determines the preliminary preparation of the ore and the subsequent treatment of the products.

Ore smelting is carried on both in shaft and in reverberatory furnaces. The following conditions determine, to a large extent which type of furnace must be used:

For the use of the shaft furnace there must be a sufficient percentage of coarse ore in the mixture to permit the passage of the blast. Fine ore cannot be used exclusively with satisfactory results. Coke and charcoal must also be available at a reasonable price. The use of the reverberatory furnace is indicated where the ore is largely concentrates or is in a pulverized condition; provided coal and fire brick and quartzose materials for lining the furnace are available at reasonable prices. Some localities furnish conditions permitting the use of both shaft and reverberatory furnaces in the same works, the former being used for the coarse ores and for slags, and the latter for finely pulverized ores. Charcoal or wood are not as satisfactory fuel as coke or coal. Shaft furnaces are generally expected to make cleaner slags than reverberatory furnaces. The selection of either type of furnace can only be determined by careful considerations of the conditions existing at any given locality.

The metallurgical practice of the Copper Queen Mining Com-

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pany of Arizona, furnishes a good example of the treatment of ores included under division I viz., copper ores proper. This company produces about two million pounds of copper per month, and has developed, under unfavorable conditions, an admirable metallurgical plant. The early operations at this mine furnished only oxidized copper ores, which were smelted in small water-jacket shaft furnaces, the product being black copper. As developments progressed, large bodies of sulphide ore were discovered, and at the present time the available ores comprise both sulphides and oxidized ores in large quantities. The smelting for black copper was discontinued and the practice now is to make a uniform mixture of both classes of ores, the copper and sulphur contents being maintained at a uniform percentage, and the ore mixture, at the same time, being self-fluxing. The amount of sulphide ores is proportioned so as to obtain, as nearly as possible, a matte containing fifty per cent. of copper, this being the most satisfactory percentage for the subsequent Bessemerizing process. At times a small percentage of the sulphide ores is roasted in a Douglas calciner. The smelting of the ore mixture is carried on in water-jacket shaft furnaces of a type peculiar to these works.

Through the kindness of Mr. James Douglass, Jr., president of the Copper Queen Mining Company, I am able to show you the working drawings of the latest furnace constructed for the company. It is a rectangular water-jacket with rounded corners, constructed without sections. The dimensions at the tuyeres are 42 by 120 inches; the height from the tuyeres to the charging door six feet, and there are eighteen tuyeres 4½ inches in diameter. The water-jacket does not extend to the bottom of the crucible, the latter being constructed of brick retained in place by the outside sheet of the water-jacket extended downwards. The tuyeres are rigidly connected with a wind-box which extends around the furnace above the tuyere openings.

Two things are especially noticeable: The large number and size of the tuyere openings, and the fact that the depth of the charge is only six feet. The blast pressure varies from twenty-six to thirty ounces. These furnaces smelt, on an average, about one hundred and ninety tons per day of ore with a consumption of about 13½ per cent. of Colorado coke containing not less than 17 per cent. of ash. A great deal of the ore comes out of the mine in a comparatively granular condition, and, as a conse-

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quence, considerable flue dust is collected. The top of the furnace is naturally quite hot; points of burning gas generally showing to some extent. The damp ore from the mine is charged so rapidly however, that the top never seems to become excessively hot. With the low charge a certain amount of sulphur is undoubtedly burned off, but how much has not yet been determined. Until very recently the matte in these large furnaces was allowed to accumulate in the crucible and from thence was tapped into the converter direct. Later, a large outside well or forehearth of wrought iron lined with converter lining was used to separate the matte and slag, and from this the charges for the converter were tapped. Owing to the difficulties occasioned by the matte breaking out from this well, and the difficulty in stopping the flow of the matte at the end of the charging operation, a new well was devised which is turned on trunnions by hydraulic power. This tilting well, so-called, gives perfect satisfaction and avoids all the difficulties enumerated above. The smelting process then is as follows:

The ore mixture is charged into the furnace and the melted products flow into the outside well, having at each end slag spouts from which the slag overflows; the matte accumulates in the well until a charge is desired for the corresponding converter. The well is then tilted and the matte poured out into a clay-lined trough which carries it into the converter. The converters are of the ordinary trough type, and are conveyed back and forth for relining by means of a small car carrying a hydraulic piston which lifts the converter from its supports.

Formerly, the matter was cast in slabs which were broken up and remelted for the converter. The lowest coke consumption for remelting the matte was eight per cent.

From this brief description you will readily notice that development here has been in the same direction as already pointed out in respect to lead smelting; namely, blast furnaces designed to give the largest output possible, and the elimination of intermediate steps in order to combine the smelting of the ore and the Bessemerizing of the matte practically in one process without remelting or rehandling the matte. The converter linings are made from crushed quartzite and clay obtained in the mines. It may be noted here that the most needed improvement in the Bessemerizing of copper matte is some method by which quartz can be fur-

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nished externally for fluxing the iron set free in the process of conversion. None of the many plans tried have been successful, and it is still necessary to furnish the silicia from the lining of the converter itself. One improvement has been made which permits the wear of the lining to a greater extent than heretofore. This consists in putting in a layer of basic bricks next to the converter shell, the ganister lining being formed inside of this layer. The shell is consequently always protected from the action of the charge. Where available, quartzose ores containing valuable metals may be used for the lining of converters, in this way their contents are gradually collected by the metal in the charge during the process of conversion.

Another improvement contemplated is the casting of copper from the converter into anodes for subsequent electrolytic refining.

The location of the works is in a narrow gulch adjoining the principal mine shafts, and, as a consequence, it has required great judgment to construct a plant which is satisfactory from a mechanical standpoint.

Each furnace is provided with a converter, and the operation of both in such a way that the product of one shall equal and not exceed the capacity of the other, furnishes an admirable illustration of good metallurgical practice.

The flue dust is made into bricks with slacked lime. These are charged, after drying, into the furnaces.

Some copper works in the West treat ores in which sulphides are in excess. Roasting them becomes necessary. Mechanical roasting has largely supplanted other processes. The only objection to mechanical roasting is the fineness of the product. Hence, where shaft furnace smelting is desirable, roasting in stalls is sometimes practiced, since this permits a larger proportion of coarse ore. Mechanical roasting as a preparation for copper smelting does not present the same disadvantages as in lead smelting, since an amount of sulphur is required in the roasted product proportionate to the copper contents, in order to furnish sulphur for the resulting matte. Practice has shown that a fifty per cent. matte is the most desirable one for subsequent Bessemer conversion; moreover, the production of matte without black copper makes cleaner slags and avoids the accumulation of chilled copper in the furnace crucibles and in the outside wells.

Division II. includes smelting processes which are best ex-

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emplified by the Montana practice. The ores tretaed are either quartzose ores, rich enough for direct smelting, or concentrates from low grade ores, or a mixture of both. The amount of silver and gold in these ores is generally an important consideration. Owing to the large amount of concentrates reverberatory furnaces are used to a large extent. The ores are roasted in mechanical roasters and fused in reverberatories, the resulting matte containing from forty to fifty per cent. of copper. The reverberatory furnaces have a capacity of from fifty to sixty tons per day; in some cases more, and are charged by cars through hoppers in the top; the slag is either skimmed into sand beds, or into running water where possible. In some cases the ashes also are carried off by running water. The matte is Bessemerized and subsequently refined by electricity. Converter slags are treated in shaft furnaces, or in some cases carried mechanically to reverberatory furnaces, and poured into the furnace when the charge is ready to tap. Only a few minutes is required to clean the slags before tapping out the whole charge. The latest reverberatory furnaces are also provided with hoppers at the top which are kept filled with coal either by conveyers or by cars running on an overhead track. Coarse ores are smelted in shaft furnaces, with converter slags, sometimes with an addition of fine ores, also. The copper blast furnaces in Montana correspond very closely with the lines of lead furnaces; a much greater depth of charge being used than is the case in the Copper Queen furnace already described. Outside wells are almost universally used for separating the matte and slag. Where the content of the precious metals is large the loss in converters is excessive, and hence the first matte is roasted and made into blister copper in reverberatory furnaces, the product being refined by electricity. Some works now in operation in the West use not more than three per cent. of copper in shaft furnace smelting and obtain a high percentage of the gold and silver in the ore. It will be noted that this is a much smaller percentage than is necessary when lead is the collector for the gold and silver. Mechanical handling in large works is introduced wherever possible, the endeavor being to make the regular operations automatic. Mechanical charging of shaft furnaces has not yet been introduced, but in view of the large capacity of the latest furnaces its desirability is indicated. In smaller furnaces the attention to the feeding is more necessary than in large furnaces, and I look in the near future for the introduction of mechanical charging.

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Division III. comprises the practice in such works as the Boston and Colorado Smelting Company, which treat custom ores exclusively. In these works the ores are roasted mechanically and smelted in reverberatory furnaces. Owing to the difficulty of obtaining copper the amount used is limited to 2½ or 3 per cent. As a consequence the resulting matte, which contains about 50 per cent. of copper, is very rich in gold and silver. This matte is treated by the Ziervogel process for silver and subsequently for gold by Pearce's process, the details of which have never been made public. One of the most interesting features of the Boston and Colorado works is the latest type of reverberatory furnace constructed by Mr. Pearce. I have here a diagram showing the development of this type of furnace at these works. It begins with the original Swansea type, which had a capacity of about nine tons, and progressively increases in size to the present furnace with a capacity of seventy tons per day, which is especially large considering that the ore mixture contains 95 per cent. of slag forming material. This latest furnace is a noteworthy exhibition of what can be done by proceeding along well-known lines a step at a time, and utilizing the experience gained at each advance before taking the next step. It has four openings on each side for manipulating the interior, and four charge openings in the roof. The firebox has a step grate and the coal is charged from above by means of a hopper. The firing arrangement is in the nature of a gas producer, the hot gases being immediately burned by means of hot air introduced through holes in the arch over the bridge. The enormous arched roof of the furnace is only nine inches in thickness, and is constructed of fire brick set on end. Charges weigh about twelve tons each and require about three and one-half to four hours for perfect fusion. The capacity of this furnace has averaged as high as seventy-two tons of ore per day, with a consumption of one ton of coal to four tons of ore. The matte is allowed to accumulate in the bottom of the furnace for one or even two weeks, thus giving a product of from twenty-five to fifty tons of matte at a single tapping. The bottom of the furnace is consequently protected nearly all the time by a layer of melted matte. This prevents the charges from sticking to the bottom and assists in making a rapid fusion. After the matte has been tapped out the first charges are made richer in copper, if possible, in order to quickly cover the bottom of the

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furnace with a layer of matte. Longitudinal air passages are constructed in the foundation under the hearth, and the air for combustion, after traversing these passages, passes up a flue at the side of the furnace and is admitted through holes at the top of the arch over the fire bridge. A separate stack is also provided for use when the furnace is being charged. The charging of dry ore produces a large quantity of dust, and formerly a considerable amount of this was carried out through the regular stack into the air, owing to the intense draft existing. In the present furnace, communication is cut off from the main stack by means of a sheet-iron damper, and a slight draft is created by means of a stack at the side, which is only used during the charging. This stack is connected with a short dust chamber, in which fine ore of considerable value is deposited. When a charge has been thoroughly melted the two doors farthest from the fire box on each side are opened, and the slag is skimmed from both sides at the same time. Four men work at this and the operation is concluded in about ten minutes. A section of the slag trough is made out of a triangular cast-iron box through which the slag flows and in which any globules of matte settle. This box has two tap holes at the side, from the upper one of which the slag is tapped after it has settled, the matte being obtained from the lower one. The whole operation of drawing the slag and recharging does not occupy more than twenty minutes. The construction and operation of these furnaces requires trained men and a high degree of technical skill. Mr. Pearce tells me that he thinks he has reached the limit of size in this furnace, and that beyond the present dimension there will be very little saving in fuel or in the cost of manipulation. The largest furnace which he has constructed has now been in operation a year and stands the wear and tear of use remarkably well. It is generally admitted that mattes such as are formed in these works are not suitable for Bessemerizing, as the unavoidable loss in gold and silver would be large.

The treatment of sulphide ores by the pyritic process has recently attracted much attention. In this process sulphur is supposed to furnish the fuel necessary for fusing the mixture, a part being oxidized, and the remainder combining with the copper to form matte. Theoretically this is perfectly possible, but in practice many obstacles have arisen, and the process has not, as yet, been proven a commercial success, although there are strong indi-

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cations that it will soon be perfected. The method has been abandoned in some places where it has been tried and pronounced successful. Several works, however, are operating on a commercial scale and are reported to obtain good results with three or four per cent. of coke in the charge and four or five per cent. of fuel used to heat the blast. Up to the present time I am informed that a hot blast is necessary, and that, with perhaps one exception, a small amount of coke is also necessary. A high concentration producing at the first operation a matte suitable for Bessemerizing is also impracticable. Of course, only ores carrying a large amount of sulphur will ever be suitable for this process, but the advantages of avoiding roasting and using but little high priced fuel are so great that the ultimate perfection of the process may be assured.

I have now outlined to you the methods by which the greater part of the copper in the West is produced. As in lead smelting, the treatment of large quantities of ore affords the best opportunities for economical work and the best commercial results. These large works offer the best opportunities for learning metallurgy, and employment in them will furnish you with the best means of supplementing your theoretical knowledge with practical experience.

CONTRIBUTIONS FROM THE ANALYTICAL LABORATORIES OF COLUMBIA UNIVERSITY.

CORRECTED ASSAYS.

By EDMUND H. MILLER.

During the last four or five years great progress has been made in assaying both in this country and in England, but on entirely different lines.

In England the advance has been mainly in the greater accuracy of their gold bullion assays. This has been obtained by more sharply defining the conditions under which each operation is performed and particularly by the use of the pyrometer, so that the cupellation is conducted at an almost uniform temperature.

In the United States the great development, aside from minor

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improvements in apparatus and charges, is taking place as a consequence of the introduction of corrected assays in connection with the Russel process. It was found that in many cases the actual yield by this process exceeded the amount presumably present from the results of ordinary assays; so the slags and cupels were ground, assayed and the silver obtained added to the result of the ordinary assay. When this was done the mill returns fell to their normal position below the assayers' figures.

The introduction of corrected assays has not only given more accurate results for silver in rich material, such as the precipitated sulphides from the Russel process, lead bullion, slimes, sweeps, mattes, etc., but it has drawn the attention of the assayer to the location of the losses in the assay of ores by assaying the slags and cupels separately and so determining the loss in each operation. Thus it has been shown that as the value of the ore in silver diminishes the percentage of loss increases, and also that the loss in assaying does not increase in all cases, as one might suppose, with the impurity of the ore.

The question, what is the best charge for a particular ore, is best answered by means of a corrected assay: for it is the charge giving the result nearest that of the corrected assay.

The following results, obtained by E. H. Hodgson and A. G. Stillwell, students in the School of Chemistry, afford a good example of this use of corrected assays.

A charge of one assay ton of litharge and a large excess of potassium cyanide as a reducing and a sulphurizing agent has come into use lately for sulphuret ores. This method is rapid, gives clean, malleable buttons, but its accuracy for silver seemed doubtful; so comparative corrected assays were made on two typical ores rich in silver; one a galena, the other a rich siliceous ore containing a little galena and malachite.

GALENA.

	NITRE METHOD.		CYANIDE METHOD.	
Charges:	Ore	1 A. T.	Ore	1 A. T.
	Litharge	1 "	Litharge	⅔ "
	Soda	1 "	Cyanide	⅓ "
	Nitre	10 grams.		
	Borax glass	10 "		

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These buttons were hard and brittle. They were scorified with 20 grams of test lead and ½ gram of borax glass. After scorification the buttons weighed
No. 1 22.12 grams. No. 2 21.98 grams.
The slags from the scorification of the buttons were combined and assayed, giving 3.15 mgs. of silver.

In the preceding charge less than 1 A. T. of litharge was used on account of the lead present in the ore.

Calculated Weight of Slags.

2½ A. T.		2⅓ A. T.	

Weights of Lead Buttons.

No. 1	32.33 grams	No. 1	20.98 grams
No. 2	32.11 "	No. 2	21.15 "

After cupelling, parting and deducting the silver in the litharge the weights of silver were:

No. 1	560.93 mgs.	No. 1	525.69 mgs.
No. 2.	566.73 "	No. 2	525.45 "

The crucible slags were in each case remelted with 2½ A. T. of litharge and 2½ grams of argol, the lead buttons cupelled, with feathers as usual, and the silver in the litharge deducted. The amounts recovered from the slags were as follows:

No. 1	3.16 mgs.	No. 1	36.96 mgs.
No. 2	2.66 "	No. 2	35.96 "

The cupels were ground and melted with litharge 2 A. T., soda ($NaHCO_3$) 1 A. T., borax glass 1 A. T., argol 2 grams. The silver recovered weighed as follows:

No. 1	7.81 mgs.	No. 1	6.26 mgs.
No. 2	8.06 "	No. 2	6.56 "

SUMMARY OF RESULTS.

	Nitre Method.		Cyanide Method.	
	No. 1.	No. 2.	No. 1.	No. 2.
Silver by uncorrected assay	560.93	566.73	525.69	525.45
Silver from slags	4.23	3.73	36.96	35.96
" " cupels	7.81	8.06	6.26	6.56
Total Silver	572.97	578.52	568.91	567.97

Two conclusions may be drawn from these results: 1st. That the use of potassium cyanide causes an extraordinary loss of silver in the slag. 2d. That this loss can not be completely recovered by reassaying.

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SILICEOUS ORE CARRYING GOLD. The charges used were similar to those already given.

NITRE METHOD.		CYANIDE METHOD.	
	From Ordinary Assays.		
No. 1.	174.88 mgs.	No. 1.	172.76 mgs.
No. 2.	173.80 mgs.	No. 2.	171.66 mgs.
	From Slags.		
No. 1.	0.40 mgs.	No. 1.	1.22 mgs.
No. 2.	0.64 "	No. 2.	2.18 "
	From Cupels.		
No. 1.	3.33 mgs.	No. 1.	4.07 mgs.
No. 2.	2.90 "	No. 2.	4.07 "
	Average Ordinary Assays.		
174.34 oz.		172.21 oz.	
	Average Corrected Assay.		
177.97		177.98	

The gold was practically the same by either method, 1.15–1.17 oz.

The results on this ore are not so striking as the preceding, but point to a loss of silver in the slag due to the potassium cyanide. To test this more fully two assays were run, A with 2 A. T. of potassium cyanide, B with 4 A. T. The results were as follows:

	A.	B.
Silver from ore	169.54	162.48
" " slag	3.45	8.68
Total	172.99	171.16

Showing that the loss of silver increases with the quantity of cyanide.

The relative merits of scorification and crucible methods may readily be tested by comparative corrected assays. In this way we have confirmed the well-known fact that the crucible assay is preferable for carbonate ores by locating an extraordinary loss of silver in the scorification slag.*

These results are sufficient to show the use of corrected assays in connection with the selection of charges and also the impor-

* QUARTERLY, January, 1896.

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tance of definitely locating the loss by assaying separately the slags and cupels.

Future development in assaying will also take place during the next few years by improvements in the methods of heating and regulating the heat. Gas is rapidly replacing coal and coke and the electric pyrometers of Le Chatelier and others are being simplified for practical use. Then we shall be able to make corrections not only for losses in the slag and cupel, but also for the loss due to volatilization.

CARBON COMPOUNDS USED IN MEDICINE. CLASSIFIED ACCORDING TO CHEMICAL STRUCTURE.

By MARSTON TAYLOR BOGERT.

First Paper.

Derivatives of Methane.

During the past decade the market has been flooded by a perfect deluge of Carbon Compounds, mainly of synthetic origin, and for use in nearly all the innumerable ills to which flesh is heir. Many attempts have been made to classify this ever-increasing mass of material; but the classification has been either an alphabetical one, for ready reference by the practitioner or druggist; or else a purely physiological one, in which substances having a similar action upon the human organism are grouped together; in both of which methods much valuable data bearing upon the relation between chemical structure and physiological action is entirely lost sight of. The object of this paper is, therefore, to present a classification of these Carbon Compounds which shall be based wholly upon chemical structure, indicating briefly their physiological action, so that, where possible, we may see more clearly the relation between the two; for the time is rapidly approaching when we shall see our Materia Medica resting upon a sound chemical foundation. This cannot be accomplished by attempting to discover from the action of a mixture of five or ten ingredients which particular substance produces which particular symptom, but by beginning at the other end of the route, with the simplest groups of elements and the

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simplest chemical compounds, and then passing on to the more complex. That is what is being done at the present time, and what has already furnished much interesting information on the physiological effect of the introduction of certain elements and groups into other compounds, so that the day is speedily dawning when it will be possible for the chemist to build up compounds which shall produce any desired physiological effect, just as readily as he can put together a chromogen and a salt-forming group and obtain a dyestuff. There is before us a most fruitful and fascinating field for research along these lines.

The subjoined list does not profess to be complete, but aims to discuss those COMPOUNDS OF CARBON which have more than a passing interest, either chemically or physiologically. Many mixtures and substances of unknown or uncertain composition have been omitted, since they contribute little of value to such a study. Dosage and method of administration have likewise been usually neglected. The material from which this paper has been compiled was drawn from all sources which were available to the writer, and they will be duly indicated in the Bibliography with which these papers will conclude.

In a bird's eye view of the field of Organic Chemistry it will be noticed that the DERIVATIVES of METHANE include the more important HYPNOTICS and ANÆSTHETICS, while the more prominent ANTISEPTICS and ANTIPYRETICS are found among the DERIVATIVES of BENZENE. Therefore, before taking up the discussion of the different members of the METHANE CLASS, a few words on the physiological side of the question may not be amiss.

The function of an ANÆSTHETIC is to abolish pain and reflex action. That it is not due to any action of the drug upon the circulatory system, but solely upon the nervous tissue, is clearly shown by the well-known experiment of the so-called "salt frog."

The sensation of pain is awakened in the cerebral centre by a stimulation of the peripheral ends of the afferent nerves, from which it passes through the nerve trunks and spinal cord to the brain. Pain may therefore be prevented in one of three ways: 1. By acting upon the peripheral ends of the nerves, so that they do not receive the impression of pain. 2. By acting upon the conducting path of the nerve trunks and spinal cord (which are usually much less sensitive than the peripheral ends), so that, although the painful stimulus may be received, it nevertheless fails

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to reach the brain, and 3. By paralyzing the cerebral centre itself. The anæsthesia produced in the first and second cases will be LOCAL; that in the third case will be GENERAL.

LOCAL ANÆSTHESIA may be produced by the direct application of a drug or by freezing. In the latter case, care must be observed not to destroy the tissues and cause subsequent ulceration.

The difficulty with all known GENERAL ANÆSTHETICS is that they do not confine their activity to the pain centre alone, but tend to paralyze the other centres as well, beginning with the most volitional, or those which serve preëminently to raise man above the beasts, and ending with the most automatic—those situated in the medulla; so that, if pushed far enough, they will all paralyze the respiration and heart. In the former case, artificial respiration may keep the blood aërated until the anæsthetic has been eliminated or destroyed and respiration regained; but in the latter case the chances are much more desperate, for when the central pumping station stops, the supply of oxygen to the tissues ceases entirely; the drug is not eliminated or destroyed, the processes of life are arrested, and death generally ensues. A good general anæsthetic should therefore act rapidly and powerfully, have no great tendency to paralyze the heart or respiration, its action should cease with the cessation of its administration, and its effects should be rapidly eliminated. The only substances which at all approach these requirements are the gases and volatile liquids; the gases are in most cases inconvenient, since they require special apparatus for their administering, so that the physician is driven to the volatile liquids, and in the DERIVATIVES of METHANE he finds his most useful general anæsthetics.

On the other hand, for the production of prolonged sleep, a substance is required whose action shall be slight yet continuous, "faint yet pursuing." The HYPNOTIC, therefore, should be a solid or liquid which can be administered by the mouth, absorbed into the blood, and continue to act for some time.

For convenience, the DERIVATIVES of METHANE have been grouped under the following headings:

1. C, CO, CO_2, CS_2, and Petroleum.
2. Hydrocarbons.
3. Haloid Ethers.
4. Alcohols.
5. Oxygen Ethers.

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6. Esters of Inorganic Oxygen Acids.
7. Aldehydes.
8. Ketones.
9. Sugars.
10. Organic Acids; their Salts, and Esters.
11. Amines.
12. Amides.
13. Cyanogen Derivatives.
14. Organo-metallic Compounds.

1. C, CO, CO_2, CS_2, PETROLEUM, ETC.

CHARCOAL, CARBO LIGNI (U. S. P.).—C. Although not properly speaking a "Derivative of Methane," CARBON has been here introduced as the real starting point for all classifications of "Carbon Compounds." As a disinfectant and absorbent it has been given with advantage in diarrhœa, dysentery, nausea of pregnancy, etc., while poultices of charcoal, bread crumbs, linseed meal, and boiling water form an excellent application for foul and gangrenous ulcers, removing the fetid odor and improving the condition of the sore (Cataplasma carbonis, of U. S. P.).

CARBON MONOXIDE, CARBONOUS OXIDE, FORMIC ANHYDRIDE, or CARBONYL—CO.—5% in the air is sufficient to produce rapid anæsthesia, convulsions and death. As a general anæsthetic it is too dangerous to be of any medicinal value. Its action is very interesting, for it has been shown that it forms a definite compound with the oxy-hæmoglobin of the blood, the CO displacing the oxygen, molecule for molecule. This CO-hæmoglobin is reduced only with the greatest difficulty, and the supply of oxygen to the tissues, to carry which is the function of the oxy-hæmoglobin, is thus entirely cut off, and death results.

CARBON DIOXIDE, CARBONIC OXIDE, CARBONIC ANHYDRIDE or CARBONIC ACID—CO_2—when present in the air to the extent of 25% causes rapid and deep insensibility, with convulsive action and asphyxia. Liquid CO_2, sold in cylinders containing 12lbs., is occasionally used to produce local anæsthesia by freezing.

BISULPHIDE OF CARBON, BISULPHURET OF CARBON, CARBONEI BISULPHIDUM (U. S. P.).—CS_2.—Air containing 10% CS_2 induces rapid anæsthesia, the recovery from which is speedy and followed by few bad after effects. It is rarely used thus in medicine, but more often as a local anæsthetic and counter irritant, although also occasionally given internally for gastric cancer, diarrhœa, dyspepsia, etc.

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PETROLEUM.—As one of the old household remedies, PETROLEUM has been considered a stimulating antispasmodic, expectorant, and diaphoretic; also valuable as an antiseptic dressing for wounds, skin diseases, etc.

Distillation products of petroleum:

RHIGOLENE.—B. P. about 18° C. Used in an atomizer as a local anæsthetic spray for minor surgical operations. It is said to produce a temperature of — 9° C.

BENZINE, BENZINUM (U. S. P.).—B. P. 50°–60° C.—Counter-irritant and parasiticide. In domestic practice it has been used for bronchial affections, worms, itch, etc.

KEROSENE.—Household remedy for various throat troubles.

VASELINE, PETROLATUM (U. S. P.).—A vacuum residum filtered through heated bone black. A most valuable bland emollient, used as the basis of many ointments, salves, etc.

TERROLINE, COSMOLIN, FOSSILIN, LUCILLIN, and ALBOLENE, are likewise refined petroleum jellies, used in the same way as vaseline.

VASOGENS are claimed to be "vaseline impregnated (?) with oxygen," and carrying various medicaments, such as iodoform, menthol, pyoktanin, etc.

PARAFFIN.—The "UNGUENTUM PARAFFINI" of the U. S. P. is a mixture of one part hard paraffin (Paraffinum durum) with three parts soft paraffin (Paraffinum liquidum), and serves as a substitute for vaseline.

OZOKERITE, EARTH WAX.—A natural paraffin, occurring as a dirty green or black wax in Galicia and the country around the Caspian Sea. It is said to possess the therapeutic properties of tar, and it has been used as a substitute for it, mixed with glycerine or linseed oil, in the treatment of skin diseases.

2. HYDROCARBONS.

All the lower aliphatic hydrocarbons act as general anæsthetics, their action being usually rapid, with but a short spasmodic period, followed by quick recovery and few disagreeable after-effects. They are, however, difficult to control, and capricious in behavior, as well as possessing a distinct tendency to paralyze the heart, so that they are rarely used except for minor operations of short duration. Some experimenters maintain that these lower hydrocarbons are without any physiological action upon the human organism whatever, and that the effects observed are due simply and solely to the exclusion of oxygen from the lungs.

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The higher hydrocarbons, on account of their greater molecular weight should be still more powerful general anæsthetics than the lower ones; but a difficulty confronts us here which opposes us in nearly all cases where we endeavor to increase the power of a compound by increasing its molecular weight, and that is the rise in boiling point and decrease in solubility which go hand in hand with an increase in the molecular weight. These higher hydrocarbons, therefore, being high boiling liquids or solids of low melting point, could only be administered by the mouth, and even then are practically without any physiological action, on account of their great insolubility.

a. Paraffin Series.—C_nH_{2n+2}.

METHANE, METHYL HYDRIDE, MARSH GAS, FIRE DAMP—CH_4.—An odorless gas, breathed without irritation, and, when present in the air to the amount of 35 per cent., slowly inducing anæsthesia, apparently without any active spasmodic stage; but it is troublesome to handle and not satisfactory for general use.

ETHANE, ETHYL HYDRIDE—C_2H_6.—An odorless gas, producing rapid anæsthesia with short spasmodic period, rapid recovery and no vomiting; but too apt to paralyze the heart.

BUTANE, BUTYL HYDRIDE, DIETHYL—$C_2H_5.C_2H_5$.—Gas, B.P. 1° C. Action similar to that of ethane.

ISO PENTANE, SECONDARY PENTANE, AMYL HYDRIDE, ETHYL ISOPROPYL, or METHYL ISOBUTYL—$(CH_3)_2$:H.C_2H_5.—Action similar to that of ethane; too rapid and dangerous. It is a colorless liquid, boiling at 31° C.

b. Olefine Series.—C_nH_{2n}.

ETHENE, ETHYLENE, OLEFIANT GAS, or ELAYL—CH_2:CH_2.—Gas. Anæsthesia rapidly produced, short spasmodic stage, speedy recovery without bad effects. A good general anæsthetic, but inconvenient on account of its gaseous state.

AMYLENE, VALERENE, PENTAL, TRIMETHYL ETHYLENE—$(CH_3)_2$ C:CH(CH_3).—A colorless liquid, boiling at about 36° C. It first appeared upon the market as "Amylene" or "valerene," and was prepared by distilling amyl alcohol with a concentrated solution of $ZnCl_2$, rectifying the product, collecting the first portion of the distillate separately, shaking it with H_2SO_4 to remove H_2O, and then separating. The product obtained was impure, of uncertain com-

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position, and was apt to contain Cl, so that it was abandoned as unreliable. Later it was resurrected under the name of "Pental," and is now quite largely used for minor surgical operations (especially by the dentists). Its users report it easy of administration, certain in action, with speedy recovery and no bad after effects. It is, however, liable to paralyze the heart, and several deaths have already resulted from its use. Recently it has been made from amylene hydrate, by heating under pressure at 100° C. with a mixture of equal parts H_2SO_4 and H_2O, distilling, washing the distillate with alkali, then with H_2O, drying and rectifying.

3. Haloid Ethers.

The introduction of a halogen into a hydrocarbon tends to increase its anæsthetic power, but also increases the danger of paralyzing the heart. The increase in the molecular weight and the consequent rise in the melting point and boiling point should likewise be borne in mind in considering the effect of the halogen.

a. Fluorine Substitutions.

Methyl Fluoride, Fluor Methane—CH_3F.—A colorless gas which was once proposed as a general anæsthetic, but which is now rarely heard of.

b. Chlorine Substitutions.

Methyl Chloride, Chlor Methane—CH_3Cl.—A colorless gas, pleasant to breathe. When the air contains 15%, rapid and deep narcosis is produced, followed by quick recovery, and rarely with any vomiting or other bad sequelæ. Considered by Dr. Richardson as one of the best and safest of all general anæsthetics, and the best of the chlorine anæsthetics. Its gaseous state, however, renders it inconvenient for every day practice, and it is, therefore, little known. Liquefied and sold in copper siphons, it has found employment as a local anæsthetic spray for severe neuralgia, etc.

Methylene Chloride, Methene Chloride, Dichlor Methane—CH_2Cl_2.—Colorless liquid, B. P. 42° C. Produces rapid and complete anæsthesia, but is not safe, and was rejected because it was difficult to obtain it sufficiently pure. It is decomposed in the light in the same manner as chloroform, so that 1% of alcohol is often added to retard this decomposition. The ordinary method of preparation is by the action of Zn and HCl upon chloroform. The so-called "Methyl bichloride," which is a mixture of one vol-

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ume methyl alcohol with four volumes chloroform, and also used as a general anæsthetic, should not be confused with this methylene chloride.

METHENYL CHLORIDE, TRICHLOR METHANE, or CHLOROFORM—$CHCl_3$.—B. P. 61°C. Anæsthetic, analgesic and antiseptic. As a general anæsthetic chloroform is more rapid in action than ether, and less apt to produce vomiting; but it is not so safe, because it is a powerful sedative and tends to paralyze the heart, while ether has a direct stimulating action upon that organ. A valuable property of chloroform, which renders it particularly useful in confinement cases, is its power of relaxing the muscles. Applied externally, it exerts an anodyne and antiseptic action. It has also been given internally. The "Chloroformum purificatum" of the U. S. P. is 99% $CHCl_3$ and 1% $C_2H_5.OH$, the alcohol being added to prevent its decomposition by the light. "Chloric ether" was a name given to a mixture of chloroform and alcohol in varying proportions which was recommended for anæsthesia under the impression that it was safer than chloroform.

CARBON TETRACHLORIDE, TETRACHLOR METHANE, or PHŒNIXIN—CCl_4.—Colorless liquid, B. P. 77° C. In this maximum chlorination product of methane we find the anæsthetic action very slow, the convulsive stage long and acute, with prolonged recovery, and dangerous depressing effect upon the heart. As a local anodyne, for tic-douloureux, neuralgia, etc., it is less irritating to the skin than chloroform.

ETHYL CHLORIDE, CHLOR ETHANE, or HYDROCHLORIC ETHER—C_2H_5Cl.—Colorless liquid, B.P. 12.5° C. Made by passing dry HCl gas through absolute alcohol, in presence of $ZnCl_2$ or other dehydrating agent. A good general anæsthetic, but too volatile for convenience; now largely used as a local anæsthetic spray, which has proven peculiarly efficient in the lancing of felons, amputation of digits, excision of ingrowing nails, and in circumcision. Its great inflammability should not be forgotten. During 1896 some 30,000 1-ounce tubes were sold in the United States. "Coryl," "Chloryl" and "Anestile" are all mixtures of methyl and ethyl chlorides in varying proportions and similarly used as local anæsthetics. Although producing a lower temperature, and, therefore, more rapid in action than ethyl chloride, there is a correspondingly greater danger of freezing the tissues. "Polychlorated ethyl chloride" is a mixture of chlorination products of ethyl chloride,

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chiefly tri-, tetra- and penta-chlor ethane, which is used externally as a local irritant and anæsthetic in the treatment of rheumatism, chronic sciatica, etc.

ETHYLENE CHLORIDE, DICHLOR ETHANE, or DUTCH LIQUID—$ClCH_2.CH_2Cl$.—Colorless liquid, B. P. 84°C. Made by action of Cl upon ethylene. Too slow in action and recovery to be used as a general anæsthetic, but is of much greater value as a local anodyne in rheumatism, neuralgia, etc.

ETHYLIDENE CHLORIDE, or 1, 1, DICHLOR ETHANE—$CH_3.CHCl_2$.—Produces rapid and quiet narcosis of short duration, and with little depressing action upon the heart. It is held by some to be of equal value with chloroform, while others regard it as unreliable, and suitable only for minor operations. It is a colorless liquid boiling at 60° C., and its greater anæsthetic activity is probably due to its lower boiling point, as compared with the isomeric ethylene chloride.

CHLOR ETHYLENE CHLORIDE, VINYL TRICHLORIDE or TRICHLOR ETHANE—$ClCH_2.CHCl_2$.—Colorless liquid, B. P. 114°C. From vinyl chloride and $SbCl_5$. Was claimed by a few to be a superior anæsthetic to chloroform or ethylene chloride, but is now rarely heard of.

1, 1, 1, TRICHLOR ETHANE, or METHYL CHLOROFORM—$CH_3.CCl_3$.—Colorless liquid, B. P. 75°C. Another chlorine derivative that has been proposed for use as a general anæsthetic.

BUTYL CHLORIDE, or CHLOR BUTANE—$C_4H_9.Cl$.—Colorless liquid, B.P. 78° C. Anæthesia too slow and profound, and accompanied by enormous reduction of temperature, which latter peculiarity, it has been suggested, might be of value in reducing very high temperatures in fevers, although the writer has not encountered any record of experiments to determine its usefulness in this direction.

ISOAMYL CHLORIDE, or 3-METHYL 1-CHLOR BUTANE—$(CH_3)_2CH.CH_2.CH_2Cl$.—Colorless liquid, B. P. 100°C. Physiological action and anæsthetic value same as for butyl chloride.

c. Bromine Substitutions.

It is interesting to note how the greater weight of the bromine atom tends to overwhelm more rapidly than chlorine the action of the hydrocarbon rest, the characteristic physiological effects of the bromine very quickly becoming dominant in the compound.

METHYL BROMIDE, or BROM METHANE—CH_3Br.—Colorless

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liquid, B. P. 4.5°C. Physiological action similar to that of ethyl bromide, but said by some to produce more irritation and salivation, to be more difficult to handle, and less steady in action; while others find it rapid, effective and safe.

METHENYL BROMIDE, TRIBROM METHANE, or BROMOFORM—$CHBr_3$.—Colorless liquid, B. P. 151°C. Anæsthetic, nervine and sedative. As an anæsthetic it is too irritant, and produces excessive cyanosis of the face. In whooping cough, however, it has proven of considerable service in diminishing the frequency and violence of the paroxysms which form the chief danger of the disease. It is prepared from NaBrO and acetone.

ETHYL BROMIDE, BROM ETHANE, or HYDROBROMIC ETHER—C_2H_5.Br.—Colorless liquid, B. P. 38°C. By inhalation, in less than one minute, ethyl bromide produces loss of sensation, although often without complete sleep or loss of reflex action, during which the sensation of pain, and, in general, the tactile senses, are no longer present, and minor operations can then be performed, such as incisions, extraction of teeth, etc. Recovery usually follows in four or five minutes, with no bad after effects. Objections that have been urged are that it does not keep well, that it is expensive, and that it is still more dangerous to the heart than chloroform.

ETHYLENE BROMIDE, or BIBROM ETHANE—$Br.CH_2.CH_2.Br$.—Heavy oily liquid, boiling at 131°C. Made by passing ethylene gas through bromine. A sedative and antiepileptic, introduced to avoid the undesirable effects produced by the alkaline bromides. When inhaled it produces marked toxic effects, and acts as a cardiac poison. It is used for epilepsy, delirium tremens, etc.

ALLYL TRIBROMIDE, GLYCERYL TRIBROMIDE, TRIBROMHYDRIN, PROPENYL TRIBROMIDE, or TRIBROM PROPANE—$Br.CH_2.CHBr.CH_2.Br$.—Colorless liquid, boiling at 220°C. and solidifying at 16°C. As a sedative, antispasmodic and anodyne, it has been used in whooping cough, asthma, hysteria, etc.

ISOAMYL BROMIDE, or 1-BROM 3-METHYL BUTANE—$(CH_3)_2.CH.CH_2.CH_2.Br$.—Colorless liquid, B. P. 120°C., prepared by the action of Br and P upon isoamyl alcohol. Germicide and antiseptic.

d. Iodine Substitutions.

The iodine atom being still heavier than bromine causes the action of the hydrocarbon part of the compound to be even more quickly obliterated, while the effect of the iodine becomes more and more prominent.

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METHYL IODIDE, or IODO METHANE—$CH_3.I$.—Heavy colorless liquid, B. P. 43° C. As a general anæsthetic its action is said to resemble that of chloroform, but it is too apt to decompose with partial liberation of its iodine. Used as a vesicant on lint, with a few drops of soda solution to neutralize any free iodine, it has been reported to blister as well as cantharides.

METHENYL IODIDE, TRI-IODO METHANE, or IODOFORM—CHI_3.—Yellow crystalline solid, M. P. 119° C. A very useful external antiseptic, possessing also anæsthetic properties. The prime requisites for an external antiseptic are that it should be sparingly soluble, not powerfully toxic and not locally irritant. Iodoform, although sparingly soluble, is yet sufficiently so to occasionally produce symptoms of poisoning, and these symptoms are just such as might be expected from a mixture of an alkyl and iodine. The special value of iodoform was supposed to be that its iodine would be set free only by living protoplasm, and would then exert its antiseptic power and kill the microbe; just as sulphur will destroy the fungi on vines, because the protoplasm of the fungus converts the S into H_2S or SO_2, by which it is itself destroyed. The great objection to the use of iodoform is its persistent repulsive odor, which is masked only with difficulty. Iodoform was at one time given internally, but this use has now been abandoned. "Iodoform absolut" is made by electrolyzing a very dilute alcoholic solution of KI. "Iodo iodoformin" is reported as "a mixture of iodine and iodoform," although its name would indicate it as being rather a mixture of iodine and iodoformin.

ETHYL IODIDE, IODO ETHANE, or HYDRIODIC ETHER—$C_2H_5.I$.—Colorless liquid, B. P. 72° C. Anæsthetic, antispasmodic, and general stimulant. When inhaled for bronchitis, dyspnœa, etc., 15 to 20 inspirations are sufficient to impregnate the system with iodine. Internally it has been employed for chronic rheumatism, scrofula, secondary syphilis, etc.

TETRA-IODO ETHYLENE, ETHYLENE PERIODIDE, or DI-IODOFORM—C_2I_4.—Yellow odorless needles, decomposed by light, containing 95.5% iodine, and proposed as a substitute for iodoform. It is now made by the action of iodine upon crude barium carbide in benzol solution.

ISOAMYL IODIDE, IODIDE OF AMYL—$(CH_3)_2CH.CH_2.CH_2.I$.—Colorless liquid, B. P. 148°C. Sedative and antiseptic, inhaled for dyspnœa and heart affections.

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4. ALCOHOLS.

In general, the narcotic power and duration of action of the alcohols, increases with the molecular weight.

METHYL ALCOHOL, WOOD ALCOHOL, RECTIFIED WOOD SPIRIT—$CH_3.OH$.—Mobile liquid, B. P. 66° C. Narcotic, sedative, and antiemetic; for diarrhœa, dysentery, fever and cough of consumption, etc. It also produces slow and incomplete anæsthesia. Rarely used now in medicine.

ETHYL ALCOHOL, ALCOHOL, or SPIRIT—$C_2H_5.OH$.—B. P. 78°C. Stimulant and irritant. Uses and physiological action too well known to require any discussion. An alcoholic solution of sodium ethylate, produced by the action of Na upon absolute alcohol, has been recommended for use as a caustic in lupus, psoriasis, and other skin diseases. Some writers speak of a 10% "aqueous" solution being employed, but this is probably an error, since the ethylate is instantly decomposed by water into NaOH and alcohol, which solution would have no advantage over an ordinary dilute alcoholic solution of NaOH.

ISOAMYL ALCOHOL, AMYL ALCOHOL, FUSEL OIL AMYL ALCOHOL—$(CH_3)_2.CH.CH_2.CH_2.OH$.—Colorless liquid of peculiar odor, boiling at 131° C. The "Alcohol amylicum" of the U. S. P. is rectified fusel oil, collected between 122.8° C. and 126.7° C. It is an active irritant poison, officinal only as a source of valerianic acid and the valerianates.

AMYLENE HYDRATE, TERTIARY AMYL ALCOHOL, or DIMETHYL ETHYL CARBINOL—$(CH_3)_2C(C_2H_5)OH$.—Liquid, B. P. 101° C., prepared from commercial amylene and H_2SO_4. A very useful hypnotic, intermediate in power between chloral hydrate and paraldehyde, and possessing also sedative and anodyne properties. It has been administered with advantage in cases of insomnia, alcoholic excitement, epilepsy, whooping cough, etc., but is not now so much used as formerly.

GLYCERINE, GLYCEROL, GLYCERINUM (U.S.P.)—$CH_2(OH).CH(OH).CH_2(OH)$.—Colorless syrupy liquid, B. P. 290° C. Physiological action slight, although it has been used internally as a feeble laxative, and externally in the treatment of various skin diseases. Its chief value, however, is as a vehicle for other medicines, the "Glycerita," or glycerites, being solutions of various drugs in glycerine. "Colligamen" are bandages prepared with glycerine and glycerine-zinc paste. "Glycozone" is claimed to be "glycerine acted upon

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(?) by ozone," and is sold as a substitute for H_2O_2 in the treatment of gastric ulcers, catarrh of the stomach, etc. For Nitro-glycerine, see Group 6, c.

MANNITE, MANNA SUGAR, FRAXININ, TRITICIN, SYRINGIN—$CH_2(OH).(CH.OH)_4.CH_2(OH)$. White crystalline solid, M. P. 166° C., possessing feeble laxative properties.

5. ETHERS.

a. Oxygen Ethers.

All the volatile oxygen ethers, with but few exceptions, possess decided anæsthetic power, and are usually much safer than the halogen anæsthetics in that they are free from the great depressing effect which the latter exert upon the heart.

METHYL ETHER, METHYL OXIDE—$(CH_3)_2O$.—Gas; produced by the action of H_2SO_4 upon methyl alcohol. Anæsthetic action rapid, followed by speedy recovery without bad after-effects. Dr. Richardson regards it as the safest and best of all known general anæsthetics, because it possesses the unique property of destroying sensibility before consciousness. Its gaseous condition is against its more general use, but this has been overcome by absorbing it in ethyl ether, the resulting solution being reported as rapid, effective and safe.

ETHYL ETHER, ETHYL OXIDE, SULPHURIC ETHER, ETHER—$(C_2H_5)_2O$.—Mobile liquid, B. P. 35° C. The most largely used and most valuable of all general anæsthetics. The "Aether fortior" of the U. S. P. is 94% ethyl ether, the remainder being alcohol and water. It is occasionally given internally as a sedative and anodyne, and is one of the constituents of "Hofmann's anodyne."

METHYLAL, METHYLENE DIMETHYL ETHER—$CH_2(O.CH_3)_2$.—Colorless liquid, B. P. 42° C. Anæsthetic, hypnotic, antispasmodic, nerve sedative, and anodyne. For producing general anæsthesia, it is unsatisfactory, since too slow in action and recovery, although practically free from danger. As a hypnotic it has been given for delirium tremens, etc., but seems to lose its power as the patient becomes accustomed to it.

DIMETHYL ACETALE, ETHYLIDENE DIMETHYL ETHER—$CH_3.CH(O.CH_3)_2$.—Colorless liquid, B. P. 64° C. A general anæsthetic, used alone or mixed with half its volume of chloroform.

ACETALE, or ETHYLIDENE DIETHYL ETHER—$CH_3.CH(O.C_2H_5)_2$.—Colorless liquid, B. P. 104° C. Hypnotic and sedative, given

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when chloral is contra-indicated. There is also a proprietary "Acetale," which is reported to be a mixture of acetic ether, oils of orange, thyme, wild thyme, cloves, lavender, lemon, rosemary and bergamot, menthol and absolute alcohol.

b. Thio Ethers.

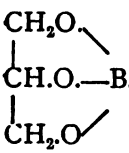
ALLYL THIO ETHER, or ALLYL SULPHIDE—$(C_3H_5)_2S$.—Liquid of powerful alliaceous odor, and boiling at 139° C. It is the principal constituent of Oil of Garlic. Medicinally it has been used as an antidiarrhœal, stomachic, and nervine; for cholera, indigestion, hysteria, &c.

6. ESTERS OF INORGANIC OXYGEN ACIDS.

a. Boric Acid.

"ANTIBACTERIN," a proprietary article, which is inhaled for tuberculosis, is said to be an ethyl orthoborate compound containing some iron. It should not be confounded with "Antibacterin-stier," which is a crude sulphate of aluminum mixed with soot.

BOROGLYCERINE, BOROGLYCERIDE, GLACIALIN, GLYCERYL BORATE—



form of boric acid. It is a useful antiseptic and preservative, occasionally given internally, but more often used as a preservative for milk, fruit, meat, etc. There is also a "Glaclalin," which is a mixture of boric acid, borax and sugar.

b. Nitrous Acid.

Nitrites, both inorganic and organic, dilate the blood vessels, thus assisting a weak heart, and lessening the danger of rupturing the vessels when the tension is high, as in the blood vessels of the kidneys during Bright's disease. Nitrites when inhaled lock up the oxygen in the oxy-hæmoglobin, so that the blood will not take up or give off oxygen as readily as usual, and only powerful reduction will remove the oxygen so that the hæmoglobin may be set free to unite with fresh oxygen; thus when the creature is nearly suffocated by this locking up of oxygen, the nitrous compound is reduced and the hæmoglobin resumes its natural functions. The isomeric nitro bodies, on the other hand, do not cause this dilation

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of the blood vessels and consequent lowering of the pressure, but tend rather, like the halogen derivatives, to produce narcosis.

ETHYL NITRITE, NITROUS ETHER—$C_2H_5.NO_2$.—Colorless liquid, B. P. 17°C. The officinal "Sweet Spirit of Nitre" (Spiritus ætheris nitrosi, U. S. P.), prepared by the action of nitric acid upon alcohol, contains about 5% of ethyl nitrite, the rest being ethyl nitrate, aldehyde and alcohol. This officinal preparation, which is largely used in febrile affections, acts as a diaphoretic, diuretic, antipyretic, antispasmodic and stimulant. "Itrosyl" is said to be "a concentrated spirit of nitrous ether."

ISOAMYL NITRITE, or NITRITE OF AMYL $(CH_3)_2CH.CH_2.CH_2.NO_2$. —Colorless liquid, B.P.99°C. The "Amyl nitris" of U.S.P. is prepared from isoamyl alcohol, sodium nitrite and H_2SO_4. It is antispasmodic, depresso-motor, and vaso-dilator, and is inhaled to relax spasms and convulsions, having proved beneficial in angina pectoris, asthma, tetanus, epilepsy, syncope, dyspnœa of Bright's disease, convulsions, chlorosis of asphyxia, etc. The isoamyl compound is more powerful in action than either ethyl or capryl, but less so than butyl.

c. Nitric Acid.

ISOAMYL NITRATE, or NITRATE OF AMYL $(CH_3)_2CH.CH_2.CH_2.NO_3$. —Colorless liquid, B. P. 88°C. Was formerly used for neuralgia of the trigeminus nerve, and in malaria.

GLYCERYL TRINITRATE, NITRO GLYCERINE, GLONOIN, TRINITRINE, or ANGIONEUROSINE—$CH_2(NO_3).CH(NO_3).CH_2(NO_3)$.—Nitro glycerine acts upon the system in a manner closely resembling that of the nitrites, except that it does not reduce the blood pressure so strongly, and its influence is felt for a much longer time. It is a very powerful drug, one-45th of a drop affecting the system strongly. The officinal preparation is a 1% alcoholic solution (Spiritus glonoini, U. S. P.), of which but one or two drops are administered at a time. It is likewise an efficient antineuralgic, and has been recently applied to the treatment of sciatica, migraine, etc.

"ERYTHROL (ERYTHRITE?) TETRANITRATE" is advertised for cardiac affections as a substitute for glonoin.

d. Phosphoric Acid.

GLYCERINO PHOSPHORIC ACID — $CH_2(OH).CH(OH).CH_2.O.PO(OH)_2$.—An inodorous oil of acid taste, made by the interaction of glycerine and phosphoric acid in presence of dehydrating agents.

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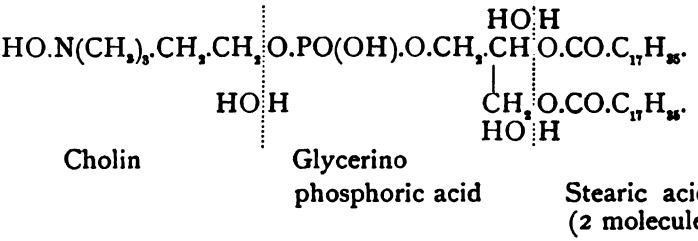
The phosphorus of the lecithin of food is converted into glycerino phosphoric acid before assimilation, hence it is the most natural form of administering this element. The breaking down of lecithin may be expressed by the following formula:



Cholin — Glycerino phosphoric acid — Stearic acid (2 molecules)

The various salts of this acid are, therefore, given to increase the phosphorus in the system of neurasthenics, and for nervous disorders of many kinds.

1. Li salt.—Nerve tonic.

2. Na salt.—For deficient nerve nutrition, neurasthenia, Addison's disease, phosphaturia, convalescence from influenza, etc.

3. NH_4 salt.—Same uses as sodium salt.

4. Mg salt.—Same uses as sodium salt.

5. Ca salt.—Nerve tonic, where lime and phosphorus are both needed, as in rachitis, wasting diseases, convalesence, etc.

e. Sulphuric Acid.

METHYL SULPHURIC ACID—$CH_3.HSO_4$.—

Na salt—$CH_3.NaSO_4,H_2O$.—A new purgative, said to act without producing any cramps.

ETHYL SULPHURIC ACID, or SULPHOVINIC ACID—$C_2H_5.HSO_4$.—

Na salt—$C_2H_5.NaSO_4,H_2O$.—A mild but active cathartic.

7. ALDEHYDES.

Many of the aldehydes possess distinct hypnotic characteristics, which are intensified by substituting the hydrogens by halogens, as is well seen by comparing the action of acetaldehyde with that of chloral. Usually the simple aldehydes exert an irritating action upon the mucous membranes, which is a great objection to their use as hypnotics; but the polymeric forms are much less objectionable in this respect.

FORMALDEHYDE—H.CO.H.—Gas; produced by the oxidation of methyl alcohol. Formaldehyde preparations:

1. Formalin, or Formol—A 40% aqueous solution. A very use-

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ful antiseptic, germicide and deodorizer; non-irritating, non-toxic and non-corrosive. For general antisepsis, as a substitute for $HgCl_2$, a ¼% to 2% solution is used; for surgery, a ¼% to ½% solution; for collyria, a $\frac{1}{10}$% solution; for hardening anatomical specimens, 4% to 10% solution; as a food preservative, 1:1000000 to 1:5000.

2. Holzin—A 60% solution in methyl alcohol, likewise used as an antiseptic and disinfectant.

3. Holzinol—A methyl alcohol solution of formaldehyde containing a small amount of menthol.

4. Carnolin—A 1½% aqueous solution, recommended as a harmless disinfectant and food preservative.

5. Steresol—A saturated solution of formaldehyde in milk sugar solution, administered as an internal antiseptic for tuberculosis, erysipelas, etc.

PARAFORMALDEHYDE, PARAFORM, or TRIFORMOL—$(H.CO.H)_x$.—White crystalline solid. Antiseptic and astringent, given internally for diarrhœa, cholera nostras, phthisis, etc., and used externally for antiseptic bandages and surgical dressings.

ACETALDEHYDE—$CH_3.COH$.—Exerts a powerful action upon the respiration. A 2% solution has been used in preserving meat, on account of its strong antiputrescent properties.

PARALDEHYDE—$(CH_3.COH)_3$— $CH_3.CH.O.CH.CH_3$ (O.CH.O, CH_3) .—Hypnotic, antispasmodic, sedative, and apparently also diuretic. It is largely used as an hypnotic, and is claimed to be safer than chloral, since it has no depressing action upon the heart. It has been given successfully in tetanus, asthma, alcoholism, etc., and does not seem to disturb the appetite or stomach. However, its taste and odor are against it, the latter persistently remaining in the breath for several hours.

METALDEHYDE—$(CH_3.COH)_3$.—White prisms. Sedative and hypnotic, for insomnia, hysteria, etc.

SULPHALDEHYDE—$(CH_3.CSH)_3$— $CH_3.CH.S.CH.CH_3$ (S.CH.S, CH_3) .—A new oily

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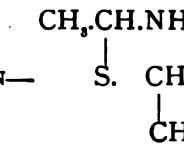
hypnotic, made by the action of H_2S upon an aqueous solution of aldehyde, and probably not pure sulphaldehyde, but a mixture of several substances of which sulphaldehyde is the most prominent. It is analogous to paraldehyde, and was claimed to be more powerful, but never rose to any importance.

THIALDIN—  .—Prismatic crystals, produced

by the action of H_2S upon an aqueous solution of aldehyde-ammonia. It has been proposed as a heart stimulant.

TRICHLOR ACETALDEHYDE, or CHLORAL—$CCl_3.COH$.—Free chloral is a colorless liquid, boiling at 98°C.; while the hydrate, which is the form in which it is usually sold, is a white crystalline solid, melting at 57°C. Chloral hydrate is an hypnotic, antispasmodic, analgesic and antiseptic, of which more than one ton is consumed daily in England and America alone. It is employed chiefly to induce sleep and relax spasm, for as an analgesic it is not so powerful as opium. Large doses cause death by paralyzing the nerve centres, arresting the action of the heart and lungs, an effect which we might have expected from the presence of the three chlorine atoms in the molecule. The hypothesis that chloral is decomposed by the alkalinity of the blood into chloroform and potassium formate seems scarcely in harmony with the facts; for chloroform has never been detected in the blood, breath or excreta, nor has formic acid been found in the urine. Chloral hydrate is the drug generally used for the so-called "knockout drops," which are so popular with criminals at the present day, and the possession of which has been made the subject of state legislation.

Chloral preparations:

1. Syrupus chloral—Chloral hydrate, simple syrup, and water.

2. Chloral camphor—Thick oil. Local anæsthetic and counter-irritant, for toothache, neuralgia, etc. Consists of equal parts chloral hydrate and camphor, rubbed up together.

3. Chloral carbol—A liquid obtained by rubbing chloral hydrate and carbolic acid together. Local anæsthetic and counter-irritant.

4. Chloral menthol—Colorless oil, prepared from equal parts chloral hydrate and menthol triturated together and then gently heated on the W. B. Local anæsthetic and counter-irritant.

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5. Chloral cyanhydrate—$CCl_3.CH(OH).CN$.—Crystalline powder, proposed as a substitute for HCN, since more permanent, and, therefore, a more exact dose can be obtained.

6. Chloral ammonium—$CCl_3.CH(OH).NH_2$.—Colorless needles, M.P. 63° C. Hypnotic and analgesic; for nervous insomnia, neuralgia, etc.

7. Chloralamide, chloral formamide—$CCl_3.CH(OH).NH.COH$.—Colorless crystals. A useful hypnotic, of doubtful anodyne action, less powerful than chloral hydrate. It has practically no effect upon the mucous membranes, and is supposed to break up in the system into chloral and formamide again. It has had some little sale as an antidote for sea-sickness. "Chlorobrom" is a mixture of chloralamide, KBr, and water, and flavored with licorice extract; it is used for the same purposes as chloralamide.

8. Chloralimide—$(CCl_3.CH:NH)_3$.—Colorless crystals. Hypnotic, analgesic and antipyretic; given to reduce fever and arrest pain, and claimed to be a superior hypnotic to chloralamide.

9. Chloralose, or anhydro gluco chloral—$C_8H_{11}Cl_3O_6$.—Comparatively soluble needles of bitter taste, prepared from anhydrous chloral and dry glucose. An hypnotic which purports to be surer than chloralamide, and to be free from the disagreeable cardiac after-effects and cumulative tendency of chloral, although it occasionally causes symptoms of intoxication. It is said to act principally by reducing the excitability of the gray matter of the brain.

10. Chloral oximes—Combinations of chloral with various oximes, which are intended for use as hypnotics. They are supposed to break up in the system into chloral and the oxime again, so that the action is essentially that of the separate constituents.

a. Chloral acetaldoxime—$CCl_3.CH(OH).O.N:CH.CH_3$.—M. P. 74°C.

b. Chloral acetoxime—$CCl_3.CH(OH).O.N:C(CH_3)_2$.—M. P. 72°C.

c. Chloral benzaldoxime—$CCl_3.CH(OH).O.N:CH.C_6H_5$.—M. P. 62°C.

d. Chloral camphoroxime—$CCl_3.CH(OH).O.N:C_{10}H_{16}$.—M. P. 98°C.

e. Chloral nitroso β. naphthol—$CCl_3.CH(OH).O.NO.C_{10}H_6$.—M. P. 100°C.

11. Spiritus ætheris chlorati—A colorless volatile liquid, pre-

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pared by distilling a mixture of MnO_2, HCl, and alcohol, and used as an excitant. It contains chloral hydrate, chloral alcoholate, ethyl chloride, aldehyde, alcohol, acetale, and higher chlorine substitutions of ethane and acetale.

META CHLORAL—$(CCl_3.COH)_x$.—Physiological action resembles that of chloral hydrate.

BROMAL HYDRATE—$CBr_3.CH(OH)_2$.—Colorless crystals, M. P. 53.5°C. Hypnotic, sedative, and antispasmodic; for epilepsy, chorea, insomnia, etc., and, in general, to relieve pain and produce sleep. The dose is about half that of chloral hydrate, after effects are generally milder, sleep is not so deep, and excitement is greater. It is not often used now.

BUTYL CHLORAL HYDRATE, BUTYRCHLORAL HYDRATE, CROTONCHLORAL HYDRATE, BUTYL CHLORAL HYDRAS (U.S.P.)—$CH_3.CHCl.CCl_3.CH(OH)_2$.—Hypnotic, analgesic, anæsthetic, and antidiabetic. Used for neuralgia of the trigeminus nerve, toothache, insomnia of heart disease, diabetes (to reduce the amount of urine passed) etc. It is a colorless crystalline solid melting at 78°C.

8. KETONES.

The sulphonal bodies have been included under the ketones, since they are derived from the latter by combination of the ketone with a mercaptan and subsequent oxidation of the resultant compound.

ACETONE, DIMETHYL KETONE—$(CH_3)_2CO$.—Colorless liquid, B.P. 56° C. A mild alterative, anthelmintic and nervine; given for rheumatism, neurosis, etc. It may also produce intoxication and sleep, but it is far less powerful than ether or chloroform. Externally it acts as a topical irritant. There is also an "Aceton," which is a proprietary grippe and headache remedy, and is not the same as this chemical acetone.

SULPHONAL, or DIETHYLSULPHONE DIMETHYL METHANE—$(CH_3)_2C(SO_2.C_2H_5)_2$.—Colorless prisms, M. P. 125° C. Hypnotic, sedative, antihydrotic and antispasmodic. Has been largely used in insane asylums, but is apt to produce toxic symptoms if continued for any length of time. It has been reported to have been given with advantage in cramps, sea-sickness, hiccoughs, etc.

TRIONAL, or DIETHYLSULPHONE METHYLETHYL METHANE—$(CH_3)(C_2H_5)C(SO_2.C_2H_5)_2$.—Colorless plates melting at 76° C. A valuable hypnotic, more active than sulphonal, and not causing

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the same drowsiness and sluggishness the following day. It acts promptly, inducing a deep and natural sleep, with no disagreeable after-effects, and exhibits also an antihydrotic action. Largely used at present.

TETRONAL, or DIETHYLSULPHONE DIETHYL METHANE—$(C_2H_5)_2C(SO_2.C_2H_5)_2$.—Colorless crystalline plates, M. P. 89° C. Another new hypnotic, reported to have all the disadvantages of sulphonal without its power, its action being more sedative than hypnotic. It is not as reliable as either sulphonal or trional, and is, therefore, rarely used.

9. SUGARS, ETC.

NITRO GLUCOSE.—Obtained by acting upon glucose with a mixture of HNO_3 and H_2SO_4. It has been used in solution as a stimulant in epilepsy and cardiac weakness.

LEVULOSE, FRUIT SUGAR, FRUCTOSE, or DIABETIN—$HO.CH_2.(CH.OH)_3.CO.CH_2.OH$.—Has been recommended for diabetic patients.

SACCHAROSE, CANE SUGAR, SUGAR, SACCHARUM (U.S.P.). $C_{12}H_{22}O_{11}$.—Sweetening agent; in powder, or as a concentrated aqueous solution (Sirupus simplex).

LACTOSE, MILK SUGAR—$C_{12}H_{22}O_{11},H_2O$.—Used in phthisis, cardiac dropsy, wasting diseases, as nourishment for babies, etc. It appears also to possess a diuretic action. "Calolactose" is reported to be a mixture of one part calomel, one part $Bi(NO_3)_3$, and eight parts lactose, and is sold as an intestinal disinfectant.

10. ORGANIC ACIDS; THEIR SALTS, AND ESTERS.

The salts of the organic acids have been included in this list to show what a minor part, after all, the organic portion of these compounds plays, as compared with that of the metal.

a. Acids $C_nH_{2n}O_2$.

FORMIC ACID, ACIDUM FORMICUM—H.COOH.—Colorless pungent liquid, boiling at 100° C. Caustic and antiseptic. Dilute solutions are used externally to stimulate the circulation in paralyzed limbs. It is rarely administered internally.

Salts:

1. Li formate—$H.COOLi+H_2O$.—For rheumatism and gout.
2. Na formate—$H.COONa+H_2O$.—A hypodermic antiseptic for surgical tuberculosis.

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3. NH_4 formate—$H.COONH_4$.—For chronic paralysis, and palsy of sensation or motion.

4. Al boroformate—A mild antiseptic and astringent, for throat diseases, etc.

Esters:

1. Ethyl formate, Formic Ether—$H.COOC_2H_5$.—Hypnotic and analgesic.

Acetic Acid, Acidum Aceticum—$CH_3.COOH$.—Colorless liquid, B. P. 118° C. The crude "Pyroligneous Acid," sometimes termed "Wood Vinegar," on account of the creosote bodies which it holds in solution, has been used as an external antiseptic and stimulant in the treatment of ulcers, gangrene, etc. Vinegar (acetum) is diuretic and refrigerant, and is useful as an antidote for alkali poisoning, to remove pieces of lime from the eye, etc. The officinal "Acidum aceticum" (U. S. P.) is a 36% solution, and was tried at one time for cancer, but proved unsatisfactory. The glacial acid may be used to remove warts, corns, etc., or to produce a rapid blister, but is never given internally.

Salts:—

1. Na acetate (Sodii acetas)—$CH_3.COONa+3H_2O$.—A weaker diuretic than the K salt. In large doses, acts as a purgative.

2. K acetate (Potasii acetas)—$CH_3.COOK$.—Diuretic, antacid, antipyretic, and mild cathartic. As is the case with most of these organic salts, the organic part is burned up in the system, leaving the metal to act as a carbonate or oxide.

3. NH_4 acetate—$CH_3.COONH_4$.—A valuable diaphoretic, refrigerant and antipyretic, largely used in febrile affections.

4. Mg acetate (Magnesii acetas)—$(CH_3.COO)_2Mg+4H_2O$.—A mild purge, proposed as a substitute for the citrate.

5. Sr acetate—$(CH_3.COO)_2Sr+\frac{1}{2}H_2O$.—Tonic and anthelmintic.

6. Al acetate—$(CH_3.COO)_6Al_2$.—Used externally as a disinfectant, and internally as a remedy for diarrhœa and dysentery.

Al subacetate.—A local astringent for various skin diseases.

Al acetoborate.—Antiseptic and disinfectant.

Al acetoglycerinate.—Antiseptic and disinfectant.

7. Zn acetate (Zinci acetas)—$(CH_3.COO)_2Zn+3H_2O$.—Astringent, antiseptic, emetic and nervine; for delirium, neurosis, etc.

8. Ferric acetate.—The various officinal solutions of ferric acetate form excellent mild chalybeates (Liquor ferri acetatis, Tinctura ferri acetatis, Mistura ferri et ammonii acetatis, etc.).

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9. Pb acetate (Plumbi acetas)—$(CH_3.COO)_2Pb+3H_2O$.—"Sugar of Lead." A powerful sedative astringent, acting as an irritant poison in overdoses. It is also used externally in the treatment of ivy poisoning.

Pb subacetate—"Goulard's Extract" is prepared by dissolving PbO in a solution of the normal acetate, and is an external astringent and sedative. There is also a diluted solution known as "Lead Water." "Goulard's Cerate" is a mixture of the subacetate with camphor cerate, and is very useful in inflammatory skin diseases.

10. Mercurous acetate—$(CH_3.COO)_2Hg_2$.—For syphilis; externally as salve, internally in pills.

11. Cupric acetate (Cupri acetas)—$(CH_3.COO)_2Cu+H_2O$.—Astringent and alterative; given internally for scrofula, epilepsy, skin diseases, etc.; externally, for conjunctivitis, gonorrhœa, etc.

Esters:

1. Ethyl acetate, Acetic ether, Æther aceticus—$CH_3.COO.C_2H_5$.—Colorless liquid of pleasant odor, boiling at 77°C. Stimulant and antispasmodic. "Migrosin" is a mixture of acetic ether and menthol sold to combat migraine. "Salubrine" is reported to consist of 25% acetic ether, 2% anhydrous acetic acid, 50% alcohol, and the balance water. It is an antiseptic, astringent and hæmostatic; and it is used, diluted with water, as a gargle, or on compresses.

Chloracetic Acid—$CH_2.Cl.COOH$.—Colorless crystals, M. P. 63°C. Caustic, astringent and hæmostatic.

Dichloracetic Acid—$CHCl_2.COOH$.—Colorless liquid, boiling at 190°C. Caustic, astringent and hæmostatic.

Thichloracetic Acid—CCl_3COOH.—Colorless crystals, M. P. 55°C. Caustic, astringent and hæmostatic; for warts, corns, nose bleed, obstinate gleet, indolent ulcers, etc.

Bromacetic Acid—$CH_2Br.COOH$.—It is interesting to note that while the sodium salt of this acid acts upon the muscles of the frog to render them as rigid as wood, the sodium salt of the unsubstituted acetic acid has no such action.

α-Amido Propionic Acid, or *α*-Alanin—$CH_3.CH(NH_2).COOH$.—The mercury salt of this acid has been proposed as a substitute for $HgCl_2$ in subcutaneous treatment.

Valerianic, Isovalerianic, Valeric, Isovaleric, Phocenic, Pentoic, or Isopentoic Acid—$(CH_3)_2CH.CH_2.COOH$.—Colorless

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liquid; B. P. 176°C. The officinal "Acidum valerianicum" is prepared by distillation of the oil or root of valerian. It has been used in various nervous disorders, and possesses properties resembling those of valerian.

Salts:

1. Li valerianate—$C_4H_9.COOLi$. Antilithic and antispasmodic; for lithiasis and rheumatism, especially rheumatism with hysteria or nervousness.

2. Na valerianate—(Sodii valerianas)—$C_4H_9.COONa$.—Nerve stimulant.

3. K valerianate—$C_4H_9.COOK$.—Stimulant; for hysteria, insanity, low fevers.

4. NH_4 valerianate (Ammonii valerianas)—$C_4H_9.COONH_4$.—Nerve tonic, for mild nervous troubles. An acid ammonium salt of the formula $C_4H_9.COONH_4 + 2C_5H_{10}O_2$, is also used in medicine.

5. Zn valerianate (Zinci valerianas)—$(C_4H_9.COO)_2Zn$.—Antispasmodic, astringent and tonic; for various nervous affections.

6. Ferric valerianate (Ferri valerianas)—$(C_4H_9.COO)_6Fe_2$.—Tonic, nervine, and emmenagogue; for anæmia, nervous exhaustion, etc.

7. Bi valerianate (Bismuthi valerianas)—$Bi_6(C_5H_9O_2)_4(OH)_8O_8$.—Sedative and antispasmodic; for neuralgia, cephalalgia, epilepsy, chorea, cardialgia, etc.

8. Quinine valerianate (Quininæ valerianas)—$C_{20}H_{24}N_2O_2.C_5H_{10}O_2$.—For nervous disorders attended with debility.

Esters:

1. Ethyl valerianate, or Valerianic ether—$C_4H_9.COO.C_2H_5$.—Colorless liquid, B. P. 134°C. Antispasmodic and sedative; for asthma and many nervous affections.

2. Isoamyl valerianate, or Apple oil—$C_4H_9.COO.C_5H_{11}$.—Colorless liquid of peculiar fruity odor, and boiling at 194°C. It is said to afford an excellent remedy for fevers and nervous troubles, and to exert a specific stimulating and sedative action upon the liver in cases of gall-stone colic.

PALMITIC ACID—$C_{15}H_{31}.COOH$.—Spermaceti (Cetaceum, U. S. P.), which is so largely used as a basis for numerous ointments and cerates, is composed mainly of the cetyl ester of this acid.

STEARIC ACID—$C_{17}H_{35}.COOH$.—Stearate of zinc is an astringent and antiseptic which is frequently employed for such diseases as gonorrhœa, atrophic rhinitis, etc.

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b. Acids $C_nH_{2n-2}O_2$.

ANGELIC ACID $\begin{matrix} CH_3.CH \\ \| \\ CH_3.C.COOH \end{matrix}$.—An aromatic tonic.

TIGLIC ACID $\begin{matrix} CH_3.CH \\ \| \\ HOOC.C.CH_3 \end{matrix}$.—Vesicant.

OLEIC ACID, ACIDUM OLEICUM—$C_{14}H_{29}.CH:CH.CH_2.COOH$.—Mainly used for the preparation of the oleates. "Lipanin" is olive oil mixed with 6% of free oleic acid.

Salts, or Oleates.—The oleates are used similarly to the ointments, but are considered to give much better absorption and to be cleaner. The officinal oleates are really solutions of the true oleates in excess of oleic acid.

1. Na oleate—$C_{17}H_{33}.COONa$.—Detergent.

2. K oleate—$C_{17}H_{33}.COOK$.—Detergent and emollient; for cleansing and healing abscesses, etc.

3. Al oleate—$(C_{17}H_{33}.COO)_6Al_2$.—Yellowish tenacious mass. An external antiseptic for skin diseases. An ethereal solution has been used as a substitute for "Traumaticin," as a protective covering for bleeding surfaces.

4. Zn oleate (Oleatum zinci)—$(C_{17}H_{33}.COO)_2Zn$.—For skin diseases, especially chronic eczema, generally mixed with vaseline (Unguentum zinci oleati).

5. Mn oleate—$(C_{17}H_{33}.COO)_2Mn$.—Inunction in anæmia, chlorosis, etc.

6. Ni oleate—$(C_{17}H_{33}.COO)_2Ni$.—An external sedative, for application in diseases of the spinal column.

7. Fe oleate—$(C_{17}H_{33}.COO)_2Fe$.—An external tonic, for administering iron by absorption.

8. Pb oleate—$(C_{17}H_{33}.COO)_2Pb$.—For skin diseases. The so-called "Lead plaster" or "Diachylon" is an oleo-palmitate of lead, prepared by boiling together a mixture of olive oil, litharge and water, and is useful in covering raw surfaces, ulcers, etc., and as the basis of other plasters.

9. Hg oleate (Oleatum hydrargyri)—$C_{17}H_{33}.COOHg$.—Oldest and most valuable of the oleates, and one of the best substances for mercurial treatment, being more readily absorbed than the ointment. There is also a double oleate of mercury and morphia, the alkaloid acting as an anodyne to allay the irritation occasion-

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ally produced by oleic acid, but the preparation does not keep well.

10. Bi oleate—$(C_{17}H_{33}.COO)_3Bi$.—Emollient and mild astringent, for skin diseases.

11. Cu oleate—$(C_{17}H_{33}.COO)_2Cu$.—For skin diseases; as yet of unknown value. There are also oleates of aconitia, atropia, morphia, quinia, strychnia and veratria.

SULPHOLEIC ACID, SULPHORICINOLEIC ACID, etc.—These acids are obtained by acting upon olive oil, castor oil, or other fixed oils, with concentrated H_2SO_4, under certain conditions. The salts are antiseptic, deodorant, and irritant, and are applied externally for ozaena, diphtheria, tuberculosis, ulcerations, and other diseases of the mucous membrane and skin. "Polysolve," or "Solvin," is the sodium salt of sulphoricinoleic acid.

c. Acids $C_nH_{2n}O_2$.

CARBONIC ACID—H_2CO_3.—The charging of a beverage with CO_2 renders it more palatable and more easily borne by the stomach.

Salts:

1. Li carbonate (Lithii carbonas)—Li_2CO_3.—The property of lithium forming a soluble salt with uric acid has suggested its use in all cases of uric acid diathesis; as in gout, calculi, etc. It exerts also a diuretic action.

2. Na carbonate (Sodii carbonas)—$Na_2CO_3 + 10H_2O$.—Has no general effect upon the system, so that it is preferable to the K salt to correct any acidity of the stomach or urine when nothing but an alkaline action is required. It may also be applied for burns.

Na bicarbonate (Sodii bicarbonas)—$NaHCO_3$.—Antacid, mild antipyretic and antiseptic; less irritating to the stomach than the neutral carbonate. It is widely used for the production of CO_2 in all kinds of effervescent beverages—as Seidlitz Powders, Granulated Citrate of Mg, Sodio Citro-tartras Effervescens, etc. The original "saleratus" of the household was $KHCO_3$, but this has now been superseded by $NaHCO_3$, "baking soda" or "cooking soda," and to which the name of "saleratus" is now frequently applied.

3. K carbonate, Salt of Tartar (Potasii carbonas)—$K_2CO_3 + 3H_2O$. Antacid, diuretic, and antilithic; for dyspepsia, dropsy, gravel, etc., and for the preparation of various effervescing mixtures.

K bicarbonate (Potasii bicarbonas)—$KHCO_3$.—Same properties and uses as the neutral carbonate, but rather milder.

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4. Rb carbonate—Rb_2CO_3.—Antacid.

5. NH_4 carbonate—The officinal "Ammonii carbonas" is probably a mixture of the bicarbonate and carbamate. It is a powerful cardiac and pulmonary stimulant, but its action is only of short duration. In sufficient amount, it is an irritant poison. It has been used for syncope, heart failure, pneumonia, phthisis, hysteria, etc., is also an expectorant, and may even be used externally as a rubefacient. Coarsely crushed with half its volume of strongest ammonia water, and scented with oil of lavender, it forms the ordinary "smelling salts."

NH_4 bicarbonate—$(NH_4)HCO_3$.—As antacid in fermentation of the stomach and as stimulant for depressed condition.

6. Mg carbonate (Magnesii carbonas)—$4MgCO_3.Mg(OH)_2.5H_2O$. —An antacid and laxative, but not so good as MgO, since it is apt to produce flatulence from the liberation of its CO_2.

7. Ca carbonate (Calcii carbonas præcipitatus)—$CaCO_3$.—Given internally for diarrhœa, or acid condition of the intestines. It is the basis of many tooth powders.

8. Zn carbonate (Zinci carbonas præcipitatus)—$2ZnCO_3.3Zn(OH)_2$.—A mild external astringent and exsiccant, antiseptic and slightly sedative, for superficial ulcers, etc.

9. Mn carbonate—$MnCO_3$.—Tonic; for chlorosis, anæmia, etc.

10. Fe carbonate—The saccharated carbonates of iron form a group of useful chalybeate preparations.

11. Pb basic carbonate, White Lead (Plumbi carbonas)—$2PbCO_3.Pb(OH)_2$.—External antiseptic, astringent and sedative; for ulcers, etc.

12. Bi subcarbonate (Bismuthi subcarbonas)—$(BiO)_2CO_3.H_2O$. A useful sedative, tonic, astringent and stomachic; for diarrhœa, nausea, and disordered condition of the alimentary canal. Externally it has been employed as a face powder.

Dithio Carbonic Acid—H_2COS_2.—The K salt has been recommended as an external antiseptic for skin diseases. It is a deliquescent orange-red crystalline powder.

Isoamyl Xanthogenic Acid—$(C_5H_{11})HCOS_2$.—The K salt has been reported as an antiparasitic.

Lactic Acid, *a*-Lactic Acid, Acidum Lacticum—$CH_3CH(OH).COOH$.—The officinal "Acidum lacticum" is a 75% aqueous solution. Caustic, astringent, digestive and antidiabetic; for dyspepsia, diarrhœa, cholera, dissolving the false membranes in diphtheritic troubles, croup, etc.

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Salts:—

1. Na lactate—$Na(C_3H_5O_3)$.—Hypnotic; for insomnia.

2. Mg lactate—$(C_3H_5O_3)_2Mg+3H_2O$.—A mild aperient.

3. Ca lactate—"Syrupus calcii lactophosphatis" of the U. S. P. is essentially a solution of Ca phosphate in lactic acid, and affords a good means of administering the former compound. It is used for scrofula, rachitis, conditions of malnutrition, etc.

4. Sr lactate—$(C_3H_5O_3)_2Sr+3H_2O$.—Anthelmintic, antinephritic and tonic. Has been tried for kidney disease on the hypothesis that it diminishes the amount of albumin without producing any diuresis.

5. Zn lactate (Zinci lactas)—$(C_3H_5O_2)_2Zn+3H_2O$.—As a remedy for epilepsy it is said to be better borne and to be more easily taken than the oxide. Externally it is used as an eye wash, etc.

6. Mn lactate—$(C_3H_5O_3)_2Mn,3H_2O$.—Tonic; for chlorosis.

7. Fe lactate.—Many lactate of iron preparations, on account of their tonic, astringent and diuretic properties, have been employed in the treatment of anæmia, chlorosis, debility, etc.

8. Bi lactate (Bismuthi lactas).—Uses and properties similar to those of the nitrate.

9. Ag lactate.—A resolvent and antiseptic, sold under the name of "Actol."

d. Acids $C_nH_{2n-2}O_4$.

Oxalic Acid, Acidum Oxalicum (U. S. P.)—$HOOC.COOH,2H_2O$.—Monoclinic crystals, M. P. 101°C.—An emmenagogue and sedative; for functional amenorrhœa and acute cystitis.

Salts:—

1. Ce oxalate (Cerii oxalas)—$(C_2O_4)_3Ce_2.9H_2O$.—Sedative and nerve tonic; for nausea of pregnancy, sea sickness, epilepsy, migraine, cardialgia, chronic diarrhœa, hysteria, etc.

2. Fe oxalate (Ferri oxalas)—$(C_2O_4)Fe,2H_2O$.—A feeble chalybeate tonic and alterative.

Succinic Acid—$HOOC.CH_2.CH_2.COOH$.—Monoclinic crystals, M. P. 185°C. Antispasmodic and diuretic.

Salts:—

1. K succinate—$(C_4H_4O_4)K_2.3H_2O$.—For delirium tremens.

2. NH_4 succinate—$(C_4H_4O_4)(NH_4)_2$.—Has been quite largely used for delirium tremens, cramps, hysteria, etc.

3. Fe succinate—$(C_4H_4O_4)Fe(OH)$.—A tonic and alterative, said to be of value as a solvent of biliary calculi.

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e. Acids $C_nH_{2n-4}O_4$.

FUMARIC ACID— $\begin{matrix} HOOC.C.H \\ \| \\ H.C.COOH \end{matrix}$.—A feeble tonic-like fumitory.

CAMPHORIC ACID, DEXTRO CAMPHORIC ACID.—Antiseptic, antihydrotic, astringent and anticatarrhal; used internally for phthisis, night sweats of consumptives (often in combination with antipyrin), chronic bronchitis, pneumonia, gonorrhœa, anginas, chronic cystitis, etc., and as intestinal disinfectant; externally, as a remedy for acute skin diseases and as an antiseptic gargle for acute or chronic diseases of the respiratory tract.

$\begin{matrix} CH_3 \\ | \\ CH_2.C.COOH \\ | \quad | \\ CH_2.C.COOH \\ | \\ C_3H_7 \end{matrix}$

Salts:—

1. Na camphorate—$(C_{10}H_{14}O_4)Na_2$.—Antiseptic.

2. K camphorate—$(C_{10}H_{14}O_4)K_2$.—Antiseptic; for night sweats of consumptives, bronchitis, cystitis, sore throat, etc.

3. NH_4 acid camphorate—$(C_{10}H_{15}O_4)NH_4.3H_2O$.—Has been recommended as a stimulant and nerve sedative.

f. Acids $C_nH_{2n-2}O_5$.

MALIC ACID—$HOOC.CH(OH).CH_2.COOH$.—Antiscorbutic and antipyretic.

Salts:—

1. Mg malate—$(C_4H_4O_5)Mg,5H_2O$.—A mild laxative and antilithic.

2. Fe malate—$(C_4H_4O_5)_3Fe_2$.—A mild chalybeate tonic and astringent.

g. Acids $C_nH_{2n-2}O_6$.

TARTARIC ACID, DEXTRO TARTARIC ACID, ACIDUM TARTARICUM (U. S. P.)—$HOOC.CH(OH).CH(OH).COOH$.—Monoclinic crystals. Refrigerant and antiscorbutic. Its physiological action resembles that of citric acid, except that it is rather more irritant. Its main use is in the preparation of various effervescing beverages, such as Seidlitz Powders, and also as a substitute for citric acid in artificial lemonade, because it is cheaper.

Salts:—

1. Li bitartrate—$(C_4H_5O_6)Li,H_2O$.—Has been used for gout.

2. Na tartrate (Sodii tartras)—$(C_4H_4O_6)Na_2,2H_2O$.—An agreea-

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ble aperient and diuretic, equal in power to $MgSO_4$, and nearly tasteless. The so-called "soda powders" form an extempore tartrate of Na somewhat aerated with CO_2.

Na borotartrate.—A mixture of Na tartrate and borax, used as an antiseptic and diuretic, for lithæmia, etc.

3. K tartrate, Soluble Tartar (Potasii tartras)—$(C_4H_4O_6)K_2.\frac{1}{2}H_2O$. —A mild cooling aperient and diuretic, occasionally combined with senna.

K bitartrate, Cream of Tartar (Potasii bitartras)—$(C_4H_5O_6)K$.—Cathartic, diuretic and refrigerant; often prescribed with senna (Confectio sulphuris), or jalap (Pulvis jalapæ compositus).

K and Na tartrate, Rochelle salt (Potasii et sodii tartras)—$(C_4H_4O_6)NaK,H_2O$. A gentle and cooling purgative. The blue paper of Seidlitz Powders contains an intimate mixture of Rochelle salt and sodium bicarbonate.

4. Cs bitartrate—$(C_4H_5O_6)Cs$.—Recommended for nervous palpitation of the heart.

5. Rb bitartrate—$(C_4H_5O_6)Rb$.—Same properties as the Cs compound.

6. NH_4 tartrate—$(C_4H_4O_6)(NH_4)_2$.—Expectorant.

7. Mg metatartrate—$(C_4H_4O_6)Mg$.—Has been proposed as a substitute for the citrate, but in power more nearly approaches the sulphate.

8. Al acetotartrate—Caustic, astringent and antiseptic; of especial value in nasal and laryngeal troubles.

Al borotartrate, Boral.—An external disinfectant and astringent; mainly employed for inflammatory diseases of the nose and throat.

9. Mn tartrate.—Has been suggested as a useful salt for administering manganese.

10. Ferric tartrate.—A mild chalybeate tonic and emmenagogue.

Potassio ferric tartrate (Ferri et potasii tartras).—An agreeable chalybeate tonic, especially good for children, on account of its slight taste and ready solubility.

Ammonio ferric tartrate (Ferri et ammonii tartras).—Another mild chalybeate.

11. Sb tartrate—$(C_4H_4O_6)(SbO)_2.H_2O$.—Given internally for skin diseases, instead of arsenic.

Sb and K tartrate, Tartar Emetic (Antimonii et potasii tartras)—Emetic, sedative, alterative, counter-irritant, antiphlogistic, diaphoretic and expectorant; for febrile affections, pulmonary trou-

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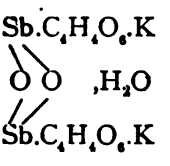


bles, etc. It is one of the constituents of the so-called "Brown Mixture," a popular cough remedy, and also of the Compound Syrup of Squills (Syrupus scillæ compositus). Recently this powerful drug has somewhat fallen into disrepute. The homeopathic remedy "Stibium" is a preparation of tartar emetic with milk sugar.

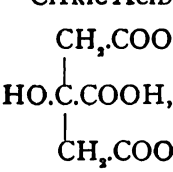
Sb and Li tartrate, Tartarlithine.—The lithium analogue of tartar emetic, and another of the numerous lithium preparations for combating uric acid diathesis.

h. Acids $C_nH_{2n-4}O_6$.

CAMPHORONIC ACID— $\begin{matrix} CH_3.CH.CH_2.COOH \\ | \\ CH_2.CH.CH_2.COOH \\ | \\ COOH \end{matrix}$.—Soluble white needles, obtained by the oxidation of camphoric acid, and recommended as an antiseptic. It is not often heard of.

i. Acids $C_nH_{2n-4}O_7$.

CITRIC ACID, ACIDUM CITRICUM (U.S.P.).—Antiscorbutic, refrigerant and antiseptic. In larger doses it may act as a poison by irritating the gastro-intestinal mucous membrane, but it is not so irritating as tartaric acid and has never caused death. It is eliminated by the kidneys, and when given in excess renders the urine acid. As a substitute for lemon juice, it keeps better, but is not so pleasant in flavor.



Salts:

1. Li citrate (Lithii citras)—$(C_6H_5O_7)Li_3$.—Acts practically the same as the carbonate, since the citric acid is burned up in the system and the carbonate results, which is finally eliminated by the kidneys. It has a less disagreeable taste than the carbonate, and is less liable to irritate the stomach.

2. Na citrate (Sodii citras)—$2(C_6H_5O_7)Na_3, 11H_2O$.—Proposed as a pleasant purgative similar to the Mg salt, but of more saline taste, cheaper, and of a constant solubility, permitting it to be mixed with other medicines. It is also a diuretic and antipyretic; used in fevers, diseases of the genito-urinary tract, etc.

Na citrotartrate (Sodio citrotartras effervescens).—Prepared from

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sodium bicarbonate, citric acid and tartaric acid. It is an effervescing draught of refrigerant laxative properties, for use in fevers, the CO_2 rendering it more acceptable to the stomach.

Na acid citrate—$(C_6H_7O_7)Na,H_2O$.—Diuretic and antipyretic, for fevers.

Na borocitrate.—A mixture of sodium citrate and borax used for anæmia, etc., as an antilithic and diuretic.

3. K citrate, Salt of Riverius (Potasii citras)—$(C_6H_5O_7)K_3$, H_2O.—A refrigerant diaphoretic for fevers. The so-called "effervescing draught" is prepared by neutralizing lemon juice (consisting essentially of citric acid), or citric acid, with potassium bicarbonate, and is borne better by the stomach on account of the CO_2 present.

4. NH_4 citrate—$(C_6H_5O_7)(NH_4)_3$.—A dilute solution (Liquor ammonii citratis, U. S. P.) is used for the same purposes as the acetate.

NH_4 citrate with Fe phosphate.—Tonic, astringent, emmenagogue, and chalybeate.

5. Mg citrate—$(C_6H_5O_7)_2Mg_3$.—"Liquor magnesii citratis" of the U. S. P. is an aqueous solution of Mg citrate and K citrate, containing also free citric acid, sugar, and CO_2. It is a mild and cooling aperient, widely and favorably known. This solution, on standing, deposits crystals of $(C_6H_5O_7)_2Mg_3$, $14H_2O$, thereby rendering the supernatant liquid useless.

Mg borocitrate.—Antilithic and antiseptic; for lithiasis, gout rheumatism, etc.

6. Mn acid citrate—$(C_6H_6O_7)Mn$.—Tonic and astringent; substitute for citrate of iron in anæmia.

7. Fe citrate (Liquor ferri citratis).—A pleasant chalybeate.

Fe and NH_4 citrate (Ferri et ammonii citras)—$(C_6H_5O_7)_2Fe_2(NH_4)_3$, $3H_2O$.—Another agreeable chalybeate, more soluble than the preceding.

Fe and Mg citrate (Ferri et magnesii citras).—Prepared by dissolving ferric hydroxide and carbonate of Mg in citric acid, and evaporating to crystals.

Fe and Bi citrate (Ferri et bismuthi citras).—Made by dissolving citrate of Bi in ammonia water and adding ammonio-citrate of iron. It has been proposed as a remedy for dyspepsia.

Fe and quinine citrate (Ferri et quininæ citras).—Tonic.

Fe and strychnine citrate (Ferri et strychninæ citras).—From iron ammonium citrate, strychnine, citric acid, and water, evaporating

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the resultant solution to crystals. Although an efficient tonic, it has no advantage over its constituents given separately. It contains about 1% of the alkaloid.

8. Ag citrate.—An external antiseptic, sold under the name of "Itrol."

9. Bi citrate (Bismuthi citras)—$(C_6H_5O_7)Bi$. Stomachic and astringent; for diarrhœa, dyspepsia, etc.

Bi and NH_4 citrate (Bismuthi et ammonii citras)—$(C_6H_5O_7)Bi.3NH_3, 3H_2O$.—Prepared by evaporating to crystals an ammoniacal solution of citrate of Bi, which it closely resembles in properties. In cases of irritation or inflammation of the gastro-intestinal mucous membrane it is much inferior to the insoluble preparations; but where there is relaxation with excessive discharges, it may be administered with advantage.

j. Acids $C_nH_{2n-2}O_8$.

Saccharic Acid—HOOC.$(CH.OH)_4$.COOH.

Salts:—

1. Ca saccharate—$(C_6H_8O_8)Ca,H_2O$.—An antacid, given for dyspepsia, flatulence, etc., particularly for children.

2. Mn saccharate.—A manganese compound which is used only occasionally.

3. Fe saccharate.—"Ferrum oxydatum saccharatum solubile" of the U. S. P., in addition to its chalybeate properties, is a very valuable antidote in cases of arsenical poisoning.

4. Pb saccharate—$(C_6H_8O_8)Pb$.—Has also found some use in medicine.

II. Amines.

Trimethylamine—$(CH_3)_3N$.—This amine is a product of albuminous fermentation, and is found in rotten cheese, in the cadaver, etc., and is the substance which causes the peculiar disagreeable pungent odor noticed in herring barrels; while dimethylamine occurs in decomposing glue. In contrast to most of the amines these two just mentioned have little toxic action upon mammals. A dilute aqueous solution of trimethylamine is sold under the name of "Aminol," and is recommended as an antirheumatic, caustic, disinfectant and antiseptic. This "Aminol" should not be confounded with "Ammonol" which is an acetanilid preparation and will be discussed later.

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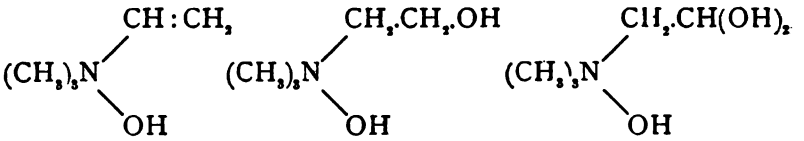
TETRAMETHYLIUM HYDRATE—$(CH_3)_4N.OH$.—A crystalline mass, a 10% solution of which has been advanced as a caustic.

TETRETHYLIUM HYDRATE—$(C_2H_5)_4N.OH$.—Crystalline solid. A 10% solution has been recommended as a uric acid solvent and antirheumatic.

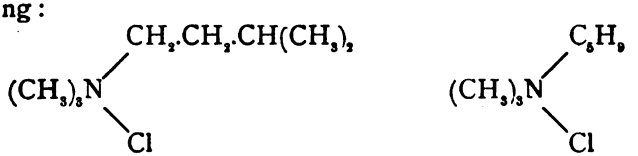
TETRALLYLIUM ALUM—$(C_3H_5)_4N.Al_2(SO_4)_3$. $12H_2O$.—Uric acid solvent.

TRIMETHYL VINYL AMMONIUM HYDRATE, or NEURIN—$(CH_3)_3N(C_2H_3)OH$.—Produced, together with neuridin ($C_5H_{14}N_2$), in the putrefaction of meat. A 3% aqueous solution is occasionally employed for painting the throat in diphtheritic affections. The relation of neurin to two other common ptomaines can be readily appreciated from the following formulæ:



Neurin. Cholin. Muscarin.

These three substances greatly resemble each other in action, although varying enormously in toxicity, muscarine being by far the most powerful. This latter body, it should be recalled, occurs not only as a ptomaine, but is also found in toadstools (*Agaricus muscarius*), of which it is the active poisonous constituent. That the poisonous activity of these compounds is not due to the presence of the OH group is evident by the similar behavior of the following:



PROPYLAMINE—$C_2H_5.CH_2.NH_2$.—The HCl salt is suggested for chorea, best with syrup of peppermint as corrigent.

AMYLAMINE—$C_5H_{11}.NH_2$.—The HCl salt forms white efflorescent scales, and is said to diminish the pulse and temperature.

SPERMINE, DIMETHYLENE IMINE—$\begin{matrix} CH_2 \\ | \\ CH_2 \end{matrix} > NH$.—A leucomaine from the seminal fluid of animals. A 2% solution of the HCl salt has been used subcutaneously in the treatment of nervous diseases complicated with anæmia.

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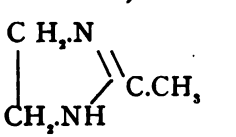
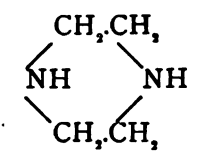
ETHYLENE DIAMINE — $NH_2.CH_2.CH_2.NH_2$.—Combined with some antiseptic and given for diphtheria. "Argentamin" is reported to be an 8% solution of silver phosphate (nitrate or chloride) in a 15% aqueous solution of ethylene diamine, and, as an antiseptic and astringent, to act more energetically than a silver nitrate solution of the same strength.

LYSIDIN, METHYLGLYOXALIDIN, or ETHYLENE ETHENYL DIAMINE—



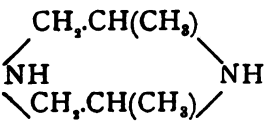
A pinkish-white crystalline solid, sold in a 50% aqueous solution. It is claimed to have five times the solvent power for uric acid that piperazine has, and not to cause any digestive troubles or albuminuria. It also appears on the market as the white crystalline bitartrate.

PIPERAZINE, PIPERAZIDIN, PYRAZINE HEXAHYDRIDE, or DISPERMINE—



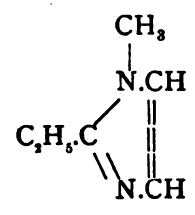
Generally sold as the crystalline HCl salt. It forms a readily soluble salt with uric acid, and is therefore largely used for gout, calculi, etc. It is believed to be more soluble than carbonate of lithium, and to dissolve much more uric acid. It has also been used for diabetes, on the supposition that it prevents the conversion of the glycogen into sugar. There is also a combination with lithium, called "Lithio Piperazine," likewise used as a uric acid solvent.

LYCETOL, or DIMETHYL PIPERAZINE.—Usually appears as the tartrate.



It is another of the numerous uric acid solvents, claimed to be better than piperazine, but not very often used nowadays.

OXALETHYLINE, METHYL ETHYL GLYOXALINE, OXAL METHYL PROPYLINE.—



Like atropine, it stimulates the brain, dilates the pupil, and paralyzes the inhibitory powers of the vagus. But if one atom of H be replaced by Cl, the resulting chlor oxalethyline, while still retaining its powers over the vagus, no longer dilates the pupil, and acts as a soporific to the brain similar to morphine.

HEXAMETHYLENE TETRAMINE, UROTROPINE, UTROPIN, or FORMIN

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—$(CH_2)_6N_4$.—A non-toxic uratolytic, increasing the excretion of urine and uric acid.

Formin preparations:—

1. Bromalin, or Bromethyl formin—A combination of ethyl bromide and formin, used as a nervine and sedative for women and children, and as a substitute for KBr in epilepsy, etc.

2. Iodoformin—Obtained by rubbing together iodoform and formin with a little absolute alcohol, until a dry powder results. Its function is as a substitute for iodoform, for moisture breaks it up into its constituents. "Iodoformin mercury" is proposed as an antiseptic.

12. Amides.

The xanthin derivatives have been included in this group, because of their close relation to uric acid.

Formamide—$H.CO.NH_2$.—An aqueous solution of the mercury compound (Hydrargyrum formamidatum solutum) is administered hypodermically as an antisyphilitic.

Succinimide—$\begin{matrix} CH_2.CO \\ | \\ CH_2.CO \end{matrix}\!\!>\!NH$.—The Hg compound is an antisyphilitic, antiseptic and alterative, given subcutaneously.

Asparagin, Asparamide, or Althein—$\begin{matrix} NH_2.CH.CO.NH_2 \\ | \\ CH_2.COOH \end{matrix}\!\!,H_2O$.—Some have recommended its use in cardiac disorders as a diuretic, while others report it to be physiologically inactive. The Hg compound is used in the same manner as in the case of the two preceding, and is dispensed as "Hydrargyrum asparaginicum."

Carbamic Acid—$HO.CO.NH_2$.—The ammonium salt of this acid is a decided stimulant.

Esters:—

1. Ethyl ester, or Urethane—$C_2H_5O.CO.NH_2$.—White crystals. It occurred to Schmiedeberg that if he could insert an alkyl radical in carbamic acid, the hypnotic action of the alkyl would be obtained, while the NH_2 group present would tend to stimulate the heart instead of depressing it as chloral and many other hypnotics do. The result of this hypothesis was Urethane, a mild and useful hypnotic, antispasmodic and sedative, of especial value for children and having less disturbing influence upon the functions of

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the organism than ony other known hypnotic. It is not, however, anodyne or analgesic to any useful extent, and is, therefore, not applicable in cases of insomnia due to pain. The urethanes containing higher alkyls should be still more powerful hypnotics, but they are all too insoluble.

CHLORAL URETHANE, URALIUM, URALINE or URAL—$CCl_3.CH(OH).NH.CO.OC_2H_5$.—White powder. Hypnotic.

SOMNAL, or CHLORAL URETHANE ALCOHOLATE—$CCl_3CH(O.C_2H_5).NH.CO.O.C_2H_5$.—Colorless crystals. Hypnotic. An alcoholic solution of chloral and urethane is also sold under this name.

UREA, or CARBAMIDE—$NH_2.CO.NH_2$.—Colorless crystals, M. P. 132° C. It has been found to act as a diuretic and uric acid solvent, free from any unpleasant symptoms.

Urea preparations:

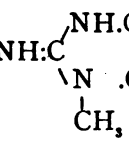
1. Hydrargyrum bichloratum carbamidatum solutum (U. S. P.).—A solution of urea in $HgCl_2$, given subcutaneously for syphilis.

2. Urisolvin—A compound of urea and citrate of lithium, proposed as a diuretic and uric acid solvent.

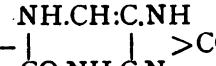
3. Citrurea—Said to be a mixture of urea, citric acid, and LiBr, and to act in the same way as urisolvin.

THIOSINNAMINE, RHODALINE, or ALLYL THIO UREA—$(C_3H_5)NH.CS.NH_2$.—Colorless crystals, M. P. 78.4° C. Escharotic and antiseptic, for hypodermic injection in skin diseases, particularly lupus.

CREATIN—$NH_2.C(:NH).N(CH_3).CH_2.COOH, H_2O$.—Transparent prisms. One of the constituents of muscular tissue, now used as a muscular and digestive tonic.

CREATININ—  .—A leucomaine from the urine, used for the same purposes as creatin. The tiring of the muscles results in the production of creatinin from creatin.

GUANIN— .—Present in the human pancreas, and here inserted to show its relation to xanthin.

XANTHIN—  .—The active stimulating principle of beef tea.

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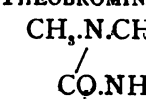
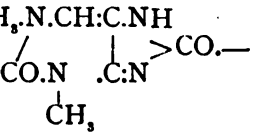
THEOBROMINE, DIMETHYL XANTHINE.—In general its properties resemble those of caffein.

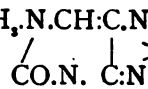


THEOPHYLLIN or DIMETHYL XANTHIN—



One of the alkaloids of tea leaves, closely related to the foregoing, and to which tea owes a portion of its stimulating properties.

CAFFEIN, THEIN, GUARANIN, CAFFEINA (U.S.P.)—$C_8H_{10}N_4O_2$.—It is a trimethyl xanthin, and is expressed by the following formula, by which its intimate relation to the preceding is clearly evident.



Caffein is a valuable cardiac and cerebral stimulant, diuretic, and muscle invigorator; for opium poisoning, nervous headaches, neuralgia, heart failure, cardiac dropsy, chronic nephritis, etc. Doses larger than ½g cause disturbances of the digestion (cramps, nausea, etc.), dizziness, and collapse, to prevent which, cocain hydrochlorate is sometimes added. Some experimenters have maintained that the action of the alkaloid obtained from tea leaves differs physiologically from that of the alkaloid prepared from coffee beans; thein acting principally upon the sensory nerves, while caffein acts mainly upon the motor nerves.

1. Caffein hydrochlorate, or muriate—$C_8H_{10}N_4O_2.HCl$, $2H_2O$.—Glassy crystals. Used for same purposes as caffein.

2. Caffein hydrobromate, or bromide—$C_8H_{10}N_4O_2.HBr$.—Glassy crystals, which become red or green on exposure. Mainly used as a diuretic.

3. Caffein hydroiodate—$C_{10}H_8N_4O_2.HI$.—White crystals. Same uses as caffein.

4. Iodo caffein, or Iodo thein—White crystals, produced by the action of H_2S upon a solution containing KI, or NaI, and caffein. Diuretic, stimulant, and alterative; chiefly used for mitral stenosis and other cardiac diseases, to increase the arterial and systolic pressure of the heart.

5. Caffein nitrate—$C_8H_{10}N_4O_2.HNO_3$, H_2O.—Same uses as caffein.

6. Caffein sulphate—$C_8H_{10}N_4O_2.H_2SO_4$.—White crystals. Same uses as caffein.

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7. Caffein phosphate—$C_8H_{10}N_4O_2.H_3PO_4$.—White crystals. Same uses as caffein.

8. Caffein acetate—$C_8H_{10}N_4O_2.(C_2H_4O_2)_2$.—White crystals. Same uses as caffein.

9. Caffein valerianate—$C_8H_{10}N_4O_2.C_5H_{10}O_2$.—Small lustrous needles. Used for nervous headaches, nervous vomiting, whooping cough and hysterical conditions with pain.

10. Caffein lactate—$C_8H_{10}N_4O_2.C_3H_6O_3$.—White crystals. Same uses as caffein.

11. Caffein malate—$(C_8H_{10}N_4O_2)_2.C_4H_6O_5$.—White crystals. Same uses as caffein.

12. Caffein citrate—$(C_8H_{10}N_4O_2).C_6H_8O_7$.—White crystals. Same uses as caffein.

13. Citrate of caffein (Caffeina citras)—$C_8H_{10}N_4O_2.C_6H_8O_7$.—Same uses as caffein. Not the same as No. 12.

14. "Citrated caffein."—Contains 50% caffein, and is not the same as either No. 12 or No. 13.

15. "Effervescent citrated caffein."—Contains only 1% of caffein.

16. Caffein borocitrate—$(C_8H_{10}N_4O_2)_3BO_3.(C_8H_{10}N_4O_2)_3.C_6H_6O_7$(?). —White crystalline powder, combining the action of caffein with the antiseptic effect of the boric acid.

17. Caffein chloral, or Chloral caffein—$C_8H_{10}N_4O_2.C_2Cl_3HO$.—Colorless crystals. Hypnotic, sedative, analgesic; for nervousness, insomnia, neuralgia and headaches. Possesses the advantage over caffein of greater solubility.

Many other caffein preparations are on the market, but those listed above will suffice to indicate how widely this alkaloid is employed.

Substituted caffeins:—

1. Caffein triiodatum, or Diiodo caffein HI salt—$(C_8H_{10}N_4O_2I_2.HI)_2.3H_2O$.—Gray-green prisms of metallic lustre, forming a mild iodine preparation.

2. Symphorol, Symphorol N, Symphoral, or Caffein sodium sulphonate—$C_8H_9N_4O^2.SO_3Na$.—Colorless crystals. The object of the introduction of the sulpho group was to counteract the irritant action of the caffein. It is a non-toxic and non-irritant diuretic. Symphorol L is the corresponding lithium salt; used for obesity, fatty heart and kidney disease, and claimed not to affect the blood pressure or depress the heart power. Symphorol S is the strontium salt.

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3. Methoxy caffein— $CH_3.N.C(O.CH_3):C.N.CH_3$ / $CO.N(CH_3).C:N$ >CO.—White needles.

For migraine and neuralgias, and, subcutaneously, for local anæsthesia.

4. Ethoxy caffein—$C_8H_9N_4O_2(O.C_2H_5)$.—Crystalline solid. Cerebro-spinal sedative, to check migraine, zona, nervous headache, neuralgia, etc. Bouchard has observed that the alkaloids formed during sleep have a stimulating action, and, by their accumulation, tend to excite the nervous system and cause the person to awaken, while the alkaloids produced during the day have a depressing effect and tend to bring about sleep. It is especially interesting in this connection to observe how the introduction of an alkyloxy group into these xanthin bodies converts a powerful cerebro-spinal stimulant into an equally powerful sedative, and there is no reason why nature should not accomplish similar results in the laboratory of the human system.

URIC ACID—$CO<^{NH.CO.C.NH}_{NH}$ ‖ $.C.NH$ >CO.—The ammonium salt has been used as an external antiseptic, for chronic cutaneous eruptions. It should be recalled that in health the greater part of the albuminous waste passes out as urea, with but a small amount of uric acid; but in various diseases the amount of uric acid is considerably increased, and even Ca oxalate occasionally appears.

13. CYANOGEN DERIVATIVES.

a. Cyanides.

HYDROCYANIC ACID, FORMONITRIL, or PRUSSIC ACID—HCN.—Sedative, anodyne, and relieves coughing. It is one of the most deadly poisons known, paralyzing the heart and respiration. One and a half grains is sufficient to kill an adult.

Salts:—

1. Na cyanide—$NaCN,H_2O$.—Sedative; for spasmodic cough and nervous irritation.

2. K cyanide (Potasii cyanidum) –KCN.—For dyspnœa, asthma, etc. Its action is the same as that of HCN, but it is more stable and therefore easier to handle. Five grains have frequently caused death.

3. Zn cyanide (Zinci cyanidum)—$ZnCy_2$.—Alterative, antiseptic

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and anthelmintic; for epilepsy, chorea, neuralgia, as substitute for HCN, etc.

4. Ag cyanide (Argenti cyanidum)—AgCN.—Antipyretic and sedative, and used for the production of HCN.

5. Hg cyanide (Hydrargyri cyanidum)—$HgCy_2$.—Alterative, antiseptic and tonic; occasionally used hypodermically for syphilis It is much less irritating than $HgCl_2$.

Hg oxycyanide—$HgO.HgCy_2$.—A non-irritating antiseptic, incorporated in gauze for wounds, etc.

6. Au cyanide (Auri cyanidum)—$AuCy_3,3H^2O$. Antisyphilitic and antitubercular.

K aurocyanide—$AuCy_3.KCy,3H_2O$. Subcutaneous antiseptic

Esters:—

1. Ethyl ester, Ethyl cyanide, Propionitril—$C_2H_5.CN$.—Therapeutic action and dose same as for HCN. These normal nitrils are comparatively harmless, while the isonitrils are exceedingly poisonous.

FERROCYANIDES:—

1. K ferrocyanide (Potasii ferrocyanidum)—$K_4FeCy_6.3H_2O$.—Sedative and astringent, for the night sweats of consumptives.

2. Zn ferrocyanide (Zinci ferrocyanidum)—$Zn_2FeCy_6,3H_2O$.—Medical properties similar to those of the cyanide.

3. Ferric ferrocyanide, Prussian blue, or Berlin blue—Fe_7Cy_{18}.—Antiperiodic, tonic and cholagogue; said to act well in intermittent and remittent fevers when quinin has failed.

b. Sulphocyanides.

POTASSIUM SULPHOCYANIDE—KSCN.—Colorless crystals. Sedative, antispasmodic and anodyne; for phthisis, cough, catarrh, dyspnœa, mania, etc.

ETHYL ISOSULPHOCYANIDE, or ETHYL MUSTARD OIL—$C_2H_5.NCS$—External local irritant, for rheumatism, neuralgia, etc.

ALLYL ISOSULPHOCYANIDE, ALLYL MUSTARD OIL, or MUSTARD OIL—$C_3H_5.NCS$.—"Oleum sinapis volatile" (U. S. P.). The active vesicant principle of the mustard plaster, produced by the decomposition of the potassium myronate (sinigrin) in the seeds, by the influence of heat and moisture combined with the action of an albuminous ferment present called "myrosin." As it says on some of the advertisements for certain mustard plasters—"it attends to its business while you attend to yours."

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14. Organo-Metallic Compounds.

Mercuric Ethyl Chloride—$C_2H_5.Hg.Cl$.—Colorless shining scales. Proposed for hypodermic injection instead of $HgCl_2$, because of its indifference to albumin.

In conclusion, the writer would apologize for the dry and uninteresting tabulations which occupy a large part of the space in this first paper, his only excuse being that along physiological lines, as well as along lines of pure chemical research, the investigations of the past few years have been confined almost exclusively to the more interesting field of aromatic chemistry and the derivatives of methane have suffered correspondingly.

A WATER MEASURING BOX.

By W. NEWBROUGH.

Considerable difficulty has been encountered in devising a box that will deliver a certain quantity of water from a ditch and at the same time be practically automatic. The accompanying sketches show a type which has given considerable satisfaction. I constructed it after the design of A. D. Foote's excess weir, changing it, however, to deliver cubic feet per second instead of miners' inches.

The contrivance is placed in the ditch as illustrated. *X* is the main ditch with a weir across the same to make still water and to direct it against a second weir *IK*. These are both weirs instead of gates, so that the velocity of approach will be a minimum and the water in the box will only have a velocity due to the fall from the wier *IK*. These weirs do not require sharp edges. The box has a board *OG* on the side toward the main ditch, whose upper edge *OG* is bevelled with the sharp edge toward the inside of the box. This is called the spill board, and over it the excess water in the box spills back into the ditch. On the other side of the box is an opening *RS*, made like a weir with sharp edges toward the inside of the box.

Suppose the box is to deliver 1½ cubic feet per second. From Frances' formula $D = 3\frac{1}{3}(l - .2H)H^{\frac{3}{2}}$, or from tables, the requisite size will be found to be 3 feet by $3\frac{7}{16}$ inches (nearly).

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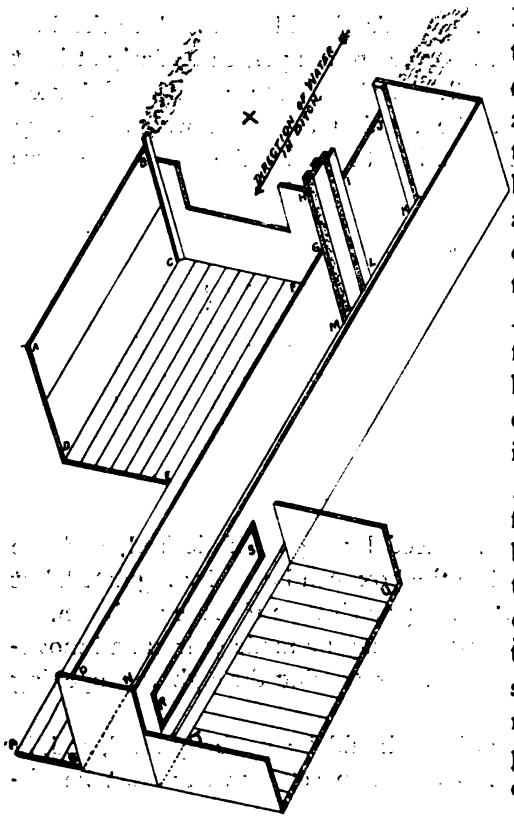

Make the opening *RS* of this size, protecting the edges by thin sheet iron, zinc or tin nailed over them, and placing the bottom of the opening at least three times $3\frac{7}{16}$, or $10\frac{5}{16}$ inches, above the bottom of the box. Also make the distance from *R* to the end of the box at least twice the depth, or $3\frac{7}{16} \times 2 = 6\frac{7}{8}$ inches. We now have $3\frac{7}{16} + 10\frac{5}{16} = 13\frac{3}{4}$ inches from the bottom of the box. This is the height to make the sharp edge of the spill board, and the spill board now serves to measure and regulate the amount passing through the opening *RS*.

The weir *IK* should be made slightly higher than the spill board—an inch or so—and the ditch weir *BG* slightly higher still. The proper heights of these last weirs can be easily and quickly determined by trial as soon as the water is running.

An apron *CE* should be built to receive the excess over the ditch weir and should be continued under the spill board. There should also be an apron, *TU*.

The plan shows some of these points more clearly.

For a box to deliver 1½ cubic feet per second, the length should be about 25 feet and the width 2½ feet, and should be made of 2 inch stuff, with 2 × 4 bracing.

Considerable difficulty is generally encountered in placing such a box. It will be noticed that the sketch shows no fluming above the ditch weir. That is because the gate *BF* is much wider than the ditch and extends a couple of feet into the bank on the side

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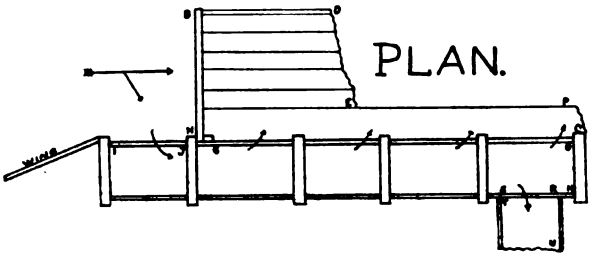
BC. Such a gate will stay. Boards should be fitted to the box around the bracing and let into the ground perpendicularly at least a foot on the side of the spill board and the apron *FPQ* butted against them. *TU* should be fixed in the same way, and every part surrounded by earth should be tamped with sand and manure mixed or clay puddled.



The weir *IK* may be replaced by a gate if desired, and the amount of water admitted to the box can be easily regulated, but there will be more velocity of approach than if made as shown.

The edge of the spill board *OG* may be made of iron and movable, and then the quantity of water passing through the opening can be changed.

It is necessary that this box should be perfectly level, and, in fact, all precautions and rules used in setting weirs must be observed.

A MINERALIZED DYKE.

By R. G. BROWN.

In the district of Sahnaripa, State of Sonora, Mexico, is a mineralized dyke, which is interesting not so much from its unusual character, as from the straightforward autobiography it furnishes.

The country-rock is porphyritic, consisting of a gray, feldspathic matrix with prismatic crystals of hornblende, but no attempt has been made to exactly determine it. The dyke in question is a diorite with finely radiating actinolite in beautiful rosettes.

This intrusion cuts squarely through the mountain, reaching a width of forty feet or more, broken at times by sharp cross faults,

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and standing nearly vertical. Roughly speaking, these are the characteristics of several sister dykes, of the same material.

The diorite is strikingly fresh and rings as clear as bell-metal, but in a few spots it is bleached to a gray color and the actinolite rosettes are faded to olive green patches.

The intrusion is "frozen" to the country rock, on either wall, but within the mass of the dyke wonderfully irregular fissures (of shrinkage, as it appears) have been formed, and in these secondary minerals have been deposited, viz., arsenical pyrites and iron pyrites (together carrying in picked samples as high as 35 ounces silver and 8 dollars gold per ton), small patches of copper pyrites, and a bluish-black bismuth-antimony-copper mineral, running to very high silver values.

In places the mineral last named has penetrated the diorite walls of the fissures to several inches, and has replaced the actinolite rays. This replacement is similar to what has been observed in the copper veins of Butte, Montana, where the blue copper ores have more or less replaced the basic portions of the exceedingly basic granite. But in that case it has not been observed, so far as the writer's knowledge goes, in the undecomposed granite, while in the case under description the diorite is usually found unchanged in other respects.

This deposit, or series of deposits, for they present an analogy with a line of mountain lakes, is allied then to Professor Kemp's division of ore bodies, II. 3, *i. e.*, "Filling joints, caused by cooling," but there is also, as seen above, a flavor of metastasis.

It is worth while to clearly review this autobiography of our mineralized dyke.

Some combination of stresses in the crust of the earth has caused a fissure, and through this, molten matter from below has been driven, perhaps by the expansive powers of steam, perhaps by the mere tendency of the fractured crust to press into the reservoir—very possibly local—of melted rock below and cause it to rise in the fissure. The filling of the fissure becomes, on cooling, our dyke, and it is naturally full of openings, due to the contraction of the material during cooling. This cooling proceeding from the walls drew the rock away from the less solidified parts of the dyke and produced cavities that are internal and not lateral, which is the more common case. The deciding factor between the two alternatives was probably due to the relative fusibility of country and intruded

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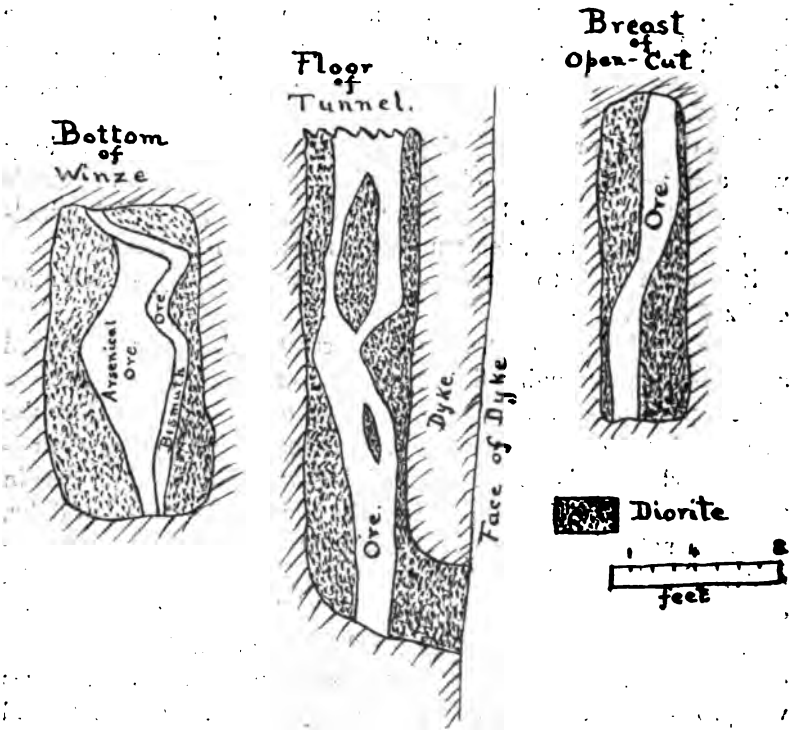
rocks. It is hardly safe to go very far in such theorizing, but it is surely reasonable to bring forward, as an hypothesis, that in cases where the intruded rock is but barely viscous it would all solidify so nearly at one time as to make the weakest line that of contact on either walls and on one of the walls to leave the open line of fissure.

But, hypothesis aside, in the present instance the contraction took place from the centre, leaving there an irregular chain of openings, which, forming a channel from depth to surface, in time were filled with minerals deposited from an aqueous solution, whose dissolving power was lessened by cooling and relaxation of pressure.

This history, of course, is familiar, and follows recognized principles in the simplest fashion, but it is of the greatest value to reiterate these principles in the various combinations of sequence and inter-relation in which they may occur.



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Description of Plate.

The three workings shown are entirely within the mass of the dyke, *i. e.*, the diorite, but only the diorite within the workings is marked with sharp hatchings.

It is noticeable that the bismuth ore occurs in tolerably distinct bands, but this is only shown in detail in the bottom of the winze.

The plate is reproduced from field sketches, but it is a notable fact, established by excavations in the floor of the tunnel, that 18 inches below the plane of the sketch the contour of the ore body is changed beyond recognition.

OPTICAL SCHEME.

By

LEA McI. LUQUER, Ph.D.

Introduction.

The scheme is designed to put before the student a short, practical way of recognizing the common minerals in rock sections.

The arrangement followed has been to group minerals having general optical characters in common, at the same time giving their specific characters* so as to make their differentiation possible.

A mere tabulation of the minerals, with a list of optical characters appended, may be of aid to the skilled investigator, but is of very little assistance to the beginner.

The more common minerals, or those which are important petrographically, are printed in heavy-faced type; the minerals of less importance in small capitals.

Abbreviations and Conventions Used.

A. = Amorphous.
I. = Isometric system.
T. = Tetragonal system.
O. = Orthorhombic system.

*For more information, regarding the optical characters of the rock forming minerals, the reader is referred to Rosenbuch's *Microskopische Physiographie der Petrographisch wichtigen Mineralien* (1892), Lévy & Lacroix's *Les Mineraux des Roches* (1888) and the writer's text-book *Minerals in Rock Sections*, now in course of preparation. Reference is also made to *Optical Mineralogy*, published by the writer in School of Mines Quarterly, Vol. XVII., p. 435, 1896.

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M. — Monoclinic system.

Tri. — Triclinic system.

H. — Hexagonal system.

M(H). — Monoclinic, with hexagonal form or characters, as in the case of biotite.

∥ — Parallel to.

⊥ — At right angles to.

El. — Elongation,* which refers to the general direction of extension that a crystal may exhibit in a rock section.

$\mathfrak{a}'$ — A direction of maximum elasticity, which need not necessarily be the axis of maximum elasticity.

$\mathfrak{c}'$ — A direction of mimimum elasticity, which need not necessarily be the axis of minimum elasticity.

(+) — Optical character positive in convergent light.

(—) — Optical character negative in convergent light.

Ex. — Extinction.

∥ Ex. — Parallel extinction, as when the crystals extinguish parallel to cleavage lines or edges. Extinction which is symmetrical to intersecting cleavage lines is also included under this term.

$(\gamma - a)$ — The difference between the indices of refraction of the two rays vibrating parallel to the axes of minimum and maximum elasticity, respectively; and indicates in decimals the relative strength of the double refraction.

The term "grains" is used to describe not only the typical granular form of epidote, but also the larger allotriomorphic occurrences of elæolite and sodalite in the plutonic rocks, as syenite, etc.

General Rules for Use of Scheme.

In each rectangle the minerals are arranged in order of their indices of refraction, those being put at the top which have the smallest index and show the lowest *relief*.

The presence or absence of *relief* is based on the way the isolated mineral appears in Canada balsam. The case might arise, however, that a mineral of high index of refraction was surrounded by minerals of only slightly lower indices of refraction; the dark border or contour would then not be distinct, but the rough appearance of the surface would still remain.

Knowing the mineral species (and, therefore, their indices of refraction) surrounding the mineral section to be determined, the index of the latter can easily be obtained by applying the following rule:

Focus sharply on the line of junction between the known and

* In crystals of long prismatic habit marked elongation would show that the section was taken approximately parallel to the vertical or prism axis. In crystals of tabular habit (the micas) marked elongation would show that the section was approximately at right angles to the tabular faces (the base in micas).

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unknown minerals;* then raise the objective slightly and the dark boundary will appear to move toward the mineral having the higher index of refraction.

Care must be taken in making use of the horizontal divisions of scheme, based on the strength of the *double refraction* and the resulting *interference colors*.† The minerals are grouped according to the interference colors given by sections of the average thickness of 0.03 mm.‡

When some known, or easily recognized, mineral in a given section shows an interference color indicating a thinner or thicker section§ allowance must be made for a similar decrease or increase in the interference colors given by all the other minerals.

The lower and middle colors of the 1st order, from bluish-gray through white to yellow, are easily recognized. The bright red, blue, green, etc., colors of the 1st, 2d and 3d orders can also be differentiated without much trouble from the very high order colors (4th and above), which show no decided tint, but are rather neutral in tone.

Confusion might come in, for example, in distinguishing at sight between the red of the 1st order and the red of the 2d order. The following simple test could then be made: Take a test-plate, giving red of the 1st order, and introduce it between the section and the analyzer, so that its axes of elasticity are parallel to the directions of elasticity in the section to be investigated.‖ When the test-plate is introduced so that dissimilar axes are superposed over those in the section, the effect is to thin the section, and its interference color drops in the color scale¶. The difference in phase of the test-plate would be just about enough to drop or lower the

*Have the convergent lens or condenser lowered and the analyzer out during this test.

†The colors vary with the thickness of the section and also with the orientation of the section in the given crystal.

‡These sections are furthermore supposed to be those producing the strongest double refraction of light and giving the highest interference colors. That is, they are supposed to be parallel to the plane containing the maximum and minimum axes of elasticity a and c.

§For instance it would not be at all strange to find quartz, in a section thicker than the average, giving the bright red of the 1st order.

‖The directions of elasticity of the section must, of course, lie at 45° to the planes of vibration of the crossed nicols in order to get the maximum interference color.

¶When the test-plate is introduced in the opposite way the effect is to thicken the section and the interference color will rise in the scale.

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color of the section through an order. Hence, if the section had previously shown red of the 1st order, the color appearing, after the introduction of the test-plate, would be a dark gray or black. If, on the contrary, the colors had been those of the upper lower 3d orders, the effect of the test-plate would be to still some bright color.

A quarter-undulation mica plate may also be conveniently used to distinguish a yellow of the 1st order from a yellow of the 2d order. If the plate be introduced in the manner just described, the effect would be to lower the color a quarter undulation. Hence, the yellow of the 1st order would change to white, while the yellow of the 2d order would change to green.

In connection with the very high order interference colors, which show no decided tint (for example, the interference colors of titanite), it must be remembered that nearly all the rock-forming minerals, having strong double refraction, have also a high refractive index; the effect of which is to give a very bright or brilliant illumination to the surface of the section, which is quite independent of the interference colors. Calcite, which has not a very high refractive index, would be an exception to this rule.

The interference figures, in convergent light, increase in clearness and distinctness with the strength of the double refraction. In uniaxial crystals sections normal to the optic axis, *i. e.*, sections which remain dark during a revolution between crossed nicols, show the best interference figures. In biaxial crystals the most characteristic interference figures are shown by sections normal to the acute bisectrix.

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			Colorless leaves or shreds (sections ⊥ tabular faces) with perfect basal cleavage. High order interference colors. Ex. about ∥. Large axial angle.	mon. Tri. CYANITE (Disthene) (—). El. ∥ c′. Colorless (may be bluish and spotted), blade-like prisms and columnar aggregates. Twinning frequent. Cleavage ∥ pinacoids. Ex. angles not very characteristic.
	DOUBLE REFRACTION Very Strong, ($\gamma - a > 0.050$.) giving INTERFERENCE COLORS higher than 3d Order. The colors have no very decided tint.	Pleochroism or Absorption		**M. Titanite** (Sphene) (+). Not very transparent, brownish to yellowish, wedge-shaped crystals or grains. Relief very high. Crystals may be twinned. The very light colored grains show no pleochroism. May be no complete extinction in white light. Ex. angles not characteristic.
		No marked Pleochroism or Absorption	**H. Calcite** (—). Colorless grains. Cleavage ∥ R. Interference colors *very* high order. Often shows polysynthetic twinning.	**H. Dolomite** (—). Like Calcite, but chiefly in crystals or with crystalline boundaries. The relief not very marked. **T. Zircon** (+). El. ∥ c′. Almost colorless, small, short, prismatic crystals. Very high relief. ∥ Ex. When included in other minerals, often surrounded by halo. **T. RUTILE** (+). El. ∥ c′. Yellowish to reddish, minute, slender prisms or grains. Grains may be almost opaque and metallic. Geniculated twins very common. Very high relief.

AGGREGATES

Serpentine, Greenish color.
Chlorite, Greenish color, usually pleochroic.
} Very low order interference colors.

Kaolinite (clay). Cloudy and scarcely translucent. No change observed between crossed nicols.

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ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF METALLURGY.

The acceptance of the chair in metallurgy by Professor Henry M. Howe inaugurated a change in the work of instruction and administration, the principal features of which are stated in the following report:

LECTURES.—The subject of metallurgy is so broad and comprehensive that the lectures have been divided, Professor Howe taking the subjects of copper, iron and steel and Dr. Struthers taking general metallurgy and the metallurgy of lead, gold, silver, and the minor non-ferrous metals. It has been deemed advisable to devote one hour a week to each class for supplementary discussion of the lectures delivered during that week. In this way the student receives individual instruction and has a better opportunity of obtaining a thorough understanding of the subject.

THE COLLECTION.—A collection of metallurgical materials and products serves two distinct purposes: first, to teach; second, to preserve. It shows the observer what materials are used and what products are made by the various metallurgical processes; and it shows him what those objects look like. It helps to make metallurgy more concrete and tangible. Quite apart from this, it preserves these various products until a time convenient for examining them. This second function is a very important one. The products of metallurgical investigations should generally, unless inconveniently large, be preserved for future reference, either to verify the original results, or to determine properties or components not originally determined, or to permit us to learn what changes take place in these objects with the lapse of years.

A great many objects which are valuable for this second purpose have very little value for the first purpose; they do not instruct the passer-by.

The opportunity offered by the removal of the collection from the old to the new site has been made use of to divide the collection into two parts, a visible and an invisible collection. The former will be deposited in the excellent cases which have been provided, while the latter will be stored in suitable boxes, but it will not be on public exhibition. It is held that the presence of objects of this second class (valuable only as objects of future investigation) among objects of the other or immediately instructive class, is very undesirable. It dilutes the collection, if one may so speak. To intersperse matter which conveys little or no immediate instruction to the passer-by, matter which for this purpose is practically dead, among objects which have immediate educational value, objects which teach something directly to the eye, diluting the instructive objects with uninstructive ones, increases the labor of the student.

It is intended later to group the materials and the products of the several most important metallurgical processes in such a way as to show, not only the general scheme of operation, but also the relative quantity of the various materials and products used or made.

THE METALLURGICAL LABORATORY.—To make metallurgical phenomena more concrete to the student, and to familiarize him with metallurgical conditions, surroundings, materials and products, a considerable amount of metallurgical laboratory work will be given to the students in

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metallurgy. During the present year this work will include the heat treatment of metals, the roasting and lixiviation of ores, and the more striking phenomena of the casting of metals, beside the use of calorimeters and pyrometers. It is believed that this work can advantageously be greatly increased in later years.

THE SUMMER SCHOOL.—The second year of the summer school in practical metallurgy was held at Chicago and Pittsburg in July, 1897, at the expiration of the summer school in mining. Professor Howe was unable to be present and the class of sixteen students in the courses of mining engineering and metallurgy was under the personal charge of Dr. Struthers.

The subject of the manufacture of iron and steel was selected, as Chicago and Pittsburg, furnishing by far the greater part of the iron and steel production of the United States, afforded the best opportunities for study.

The subject was divided into blast furnace practice, open hearth steel, Bessemer steel, crucible steel and pit practice, and detailed study was carefully made at the following works: The Illinois Steel Company at South Chicago, Bridgeport and Joliet; The Iroquois Furnaces at South Chicago; The Carnegie Steel Company, of Pittsburg, comprising the Edgar Thomson Works at Bessemer; the Homestead Works at Munhall and the recently equipped furnaces at Duquesne, and the Black Diamond Steel Company at Pittsburg.

A minor trip was made to the Cambria Iron Company at Johnstown, where, in addition to the iron and steel manufacture, the recently constructed Otto-Hoffman coking plant for saving the by-products of manufacture was visited.

A trip was also made to the lead desilverizing and refining plant of the National Smelting and Refining Company at South Chicago.

The work accomplished was as thorough as the limited time permitted. The requirements were closely adhered to and comprised all the important data relative to the subject, including the description of the process as employed at the special works visited, sketches of furnaces and special apparatus with dimensions, calling for plans, sections, and elevati the chemistry of the process, the mechanical handling of materials, l. or, etc. Class and individual instruction were given by Dr. Struthers and note books freely used. These books were corrected at the completion of the work allotted for the day and criticisms made that night or the follc ing morning while the subject was fresh in mind. It was the aim of t instruction to teach the student to observe carefully all matters of impo. tance pertaining to the work detailed and in addition to developing thus his powers of observation he was taught to reason for himself, so that he would thoroughly understand the rationale of a process and be able not only to give a clear and concise description, but also to make creditable criticisms where processes varied in method.

While the work of instruction, being carried on single handed, was of lengthy and arduous character (all books were corrected and marked at night), the satisfaction of having the students do good work was a cheering recompense for the extra exertion demanded.

The following list of requirements is appended to show the thoroughness of the work called for.

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COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK.
SCHOOL OF MINES.

SUMMER SCHOOL IN PRACTICAL METALLURGY (Second Year).

Scheme of Study: The Manufacture of Iron and Steel.

BLAST FURNACE PRACTICE.

General Description.

Sketch outline plan of works, including furnaces, stoves, blast engine and boiler-houses, stock yard, bins and chimney.

Detailed Description.

BLAST FURNACE—(State all dimensions when procurable). Describe construction as follows: Gas take-off; down comer; dust catcher; explosion doors; charging apparatus; shaft, construction and support; mantle ring and columns; bosh, construction and support; tuyere jacket and breasts; crucible jacket; iron tap and cinder notch.

State the following dimensions: Height of furnace; height to stock line; height of bosh; height of inwalls; height of hearth; height of tuyeres; diameter of throat; diameter of bosh; diameter of inwalls at the bottom; diameter at tuyere; diameter at hearth; number of tuyeres; diameters of tuyeres and total cubic capacity of furnace.

Prepare a detailed sketch of tuyere stock and give a full description of water cooling the different parts of the furnace.

HOT BLAST STOVES—Number per furnace; kind; sketch horizontal and vertical sections, giving outside dimensions of height and diameter; materials of construction; sizes of brick used and arrangement; cubic contents and square feet of heating surface; detailed sketch of gas, blast, and chimney valves.

[illegible]GE—Describe method of changing from air to gas; state the temperature to which the blast is heated at beginning of charge and at end of interval; state length of time between charges.

BLAST ENGINES—General description; number and kind; arrangement of air and steam cylinders; diameter of steam cylinder; length of stroke; number per minute; pressure; diameter of air cylinder; volume and pressure of blast produced; type of valves.

BOILER-HOUSE—General description.

ORE, FLUX, AND FUEL SUPPLY. *General description*—Method of transporting materials in stock yard to bins and furnaces, with detailed description of charging.

BLAST FURNACE WORKING. *Detailed description*—Kind of ore; yield of ore; kind of flux and composition; kind of fuel; quantity of fuel per ton of iron; quantity of flux per ton of iron; production of furnace per 24 hours; amount, pressure and temperature of blast; rate of descent of charge; temperature of gases from furnace top; methods of removal and disposal of iron and slag and times of tapping.

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OPEN HEARTH STEEL.

General Description.

Outline sketch of plan of works, including stock yard, boiler-house, producers, furnaces, cranes and casting pit.

Detailed Description.

GAS PRODUCERS—Number and kind; describe construction and method of charging and working; kind of coal used and composition of resultant gas.

FURNACE. *Construction*—Detailed sketch showing plan, elevation and section, including hearth area; number, arrangement and area of gas and air ports; distance between ports; height of roof from hearth; charging and working doors; tap hole. Cubic capacity of regenerators and arrangement of bricks; estimated heating surface in square feet; detailed description of valves and method of reversing flame direction.

FURNACE. *Working*—Capacity; composition and amounts of materials charged; method of charging; control of heat; thickness of molten metal on hearth; removal of molten products from furnace; method of recarburizing and control of the progress of the operation; repairs to hearth and lining; time of melting down, finishing and recarburizing; tapping and repairs; percentage of loss of iron.

BESSEMER STEEL.

General Description.

Outline sketch of plan of works, including stock yard; cupolas; converters in use, drying and repairing; blast engine and boiler-houses; casting pit.

Detailed Description.

CONVERTER. *Construction*—Describe materials of construction and how supported; make detailed sketch of hemlet, body and bottom and show how held together; state thickness and composition of lining and describe method of lining the bottom. *Working*—Capacity; amount and pressure of blast; thickness of molten metal; detailed description of charging, blowing, pouring, recarburizing and teeming; state the times of the different stages and description of flame.

CRUCIBLE STEEL.

General Description.

Outline plan of works and briefly describe the process.

Detailed Description.

Prepare plan, elevation and section of furnace; size and capacity of crucible; composition of materials treated and product; method of charging, operating and teeming; details of moulds.

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PIT PRACTICE.

General Description.

Sketch plan of casting pit; briefly describe method of handling molten steel, ingots and moulds.

Detailed Description.

LADLE—Sketch showing method of tapping; state materials of construction and method of operating.

CRANES—General sketch.

REHEATING FURNACES AND SOAKING PITS—Details of construction.

CHARGERS AND MOULDS—General description.

ROLLING—Sketch plan of works; detailed sketch of rolls giving type, width, diameter of rolls, outline sketch of passes; describe the method of operating.

HAMMERS, PRESSES AND SPECIAL APPARATUS—Such details as shall be designated.

In conclusion, the Department of Metallurgy wishes to publicly acknowledge its grateful thanks due to the officers of the companies visited. Their hearty courtesy and kind coöperation, so fully extended, made the visits pleasant as well as instructive.

As before mentioned in connection with the first year of the summer school,* it is to be hoped that this important factor in the instruction of metallurgy will be made permanent. Metallurgy is so eminently practical that the lectures should be supplemented by practical work of this character in order that the student should possess a rounded knowledge of the subject.

DEPARTMENT OF MINING.

The Summer School of Mining was held this year at Ishpeming, Michigan. To arrange for the session Adjunct Professor Peele left New York May 28th, and the regular underground work was begun on June 7th. Up to June 5th the class was occupied with Dr. Van Ingen in field geology, partly during stop-overs on the journey out to Michigan, and partly in the vicinity of Marquette and Ishpeming.

By the kind permission of Captain Thomas Walters, Superintendent of the Pittsburg and Lake Angeline Iron Company, of Ishpeming, the three mines of this company were thrown open to the students, with the most complete freedom for carrying on the class work. The usual detailed study of the operations of mining and the various plants employed, together with the mine survey, lasted four weeks. Short trips were made also in the large Lake Mine of the Cleveland Cliffs Iron Company, and the Section 16 Mine of the Lake Superior Iron Company. On July 5th the class went to Houghton, Mich., where several days were spent in visits to the Atlantic copper mine and mill, the extensive surface plants of the Calumet and Hecla and the Tamarack mines, and the Calumet

* SCHOOL OF MINES QUARTERLY, Vol. XVIII., No. 1, p. 65.

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and Hecla mills at Lake Linden. Some members of the class visited also the copper smelter at Hancock, and the Quincy mine. The class joined Dr. Struthers on July 10th, at Chicago, for the metallurgical work.

The Summer School was attended by 17 students, of whom 14 are regular members of the Fourth Class, 2 are graduates of Stevens Institute, and one a graduate of Johns Hopkins University. The three last mentioned joined the class with the intention of entering the School of Mines this fall. Two members of the present Fourth Class, who attended last year's Summer School at Butte, Montana, made special trips to the West during the summer for further study.

Professor Peele was assisted by Messrs. A. J. Campbell and G. S. Brackett, the former having charge of the mine surveying, which was done in the East, or Lake, mine, of the Lake Angeline Company. Very satisfactory results were obtained in running closed survey lines through vertical and inclined shafts and winzes, and the difficulties encountered in setting up the instruments while traversing the underground electric haulageways afforded good practice.

Most of the regular underground study was done in the East mine. The basin-shaped deposit is systematically worked by the top-slice caving system, the production being about 1,400 tons per day. In the West mine of the same company a composite system has been employed. The soft ore of this mine was opened up originally by room and pillar. All of the rooms have been exhausted, and the pillars are now being mined by an adaptation of the caving system. The hard ore occurring in a portion of the mine is worked by inclined "raise stopes" of large dimensions. In an adjoining (and connecting) mine, owned by the Lake Superior Company, the class had an opportunity to see chamber mining on an extensive scale. The Cleveland Lake mine, visited last, furnished an example of room and pillar work, carried out with great regularity, but not with entire success. A part of this deposit is now being "stripped." The group of iron mines studied by the class is situated on the shores of, and partially underlies, what was formerly Lake Angeline. This lake, a few years ago, was drained by pumping, but the enormous mass of soft mud lying in the basin above the ore is still a source of some embarrassment to the Cleveland Lake mine. The mud dries very slowly, and is even now covered only by a thin and flexible crust.

The facilities for the work of the class, so kindly and liberally extended by Capt. Walters, were greatly appreciated, and to him and his staff, including Mr. E. F. Bradt, the engineer of the company; Capt. W. T. Tregambo, the general underground foreman; Mr. R. T. Smith, the master mechanic, and Messrs. C. T. Hodge and C. F. Bellamy, shift bosses, are due our thanks. It is desired also to recognize here the kindness of Mr. James E. Jopling, engineer of the Cleveland Cliffs Iron Company, and of Mr. F. McM. Stanton, manager of the Atlantic Copper mine.

ELECTRICAL ENGINEERING DEPARTMENT.

The offices, laboratories, lecture and other rooms of the Electrical Engineering Department are in the south end of the Engineering Building, at the new site of the University. In the sub-basement are located the storage battery and photometer rooms. The former will be provided with a

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battery of 70 cells, which is used for efficiency and output tests and also as a source of steady potential and current. The photometer room will be equipped with all necessary apparatus for determining the candle power of arc and incandescent lamps as well as other sources of light. In the basement are situated the two machine laboratories, the larger being occupied by the direct current machinery, while the smaller contains the alternating current apparatus. In the former, a 50 h. p., high-speed steam engine drives two lines of shafting carrying pulleys controlled by friction clutches, to which the various machines are belted. The arrangement of the engine and shaft is such that two dynamos of 30 kilowatts each can be connected to the engine, or either machine may be used as a motor to drive the shafting, the current being obtained from the electric light and power plant of the University. In this way the breaking down of the motive power is rendered almost impossible and an excellent demonstration of the two methods of driving is made.

The various dynamos which are belted to the line shaft include examples of 115, 230, and 500 volt constant potential generators, constant current arc-lighting dynamos, and other typical machines. Several types of stationary and railway motors, as well as motor dynamos are also placed in this room. Machine and hand tools are provided in one corner of this laboratory for making and repairing apparatus, attachments, etc. Complete sets of ampere and volt meters, speed indicators, transmission and absorption dynamometers, etc., are available for testing the various dynamos and motors.

In the other machinery laboratory, the alternating current apparatus is placed, including single phase and polyphase generators, induction and synchronous motors, as well as various types and sizes of transformers. Complete sets of alternating current measuring instruments and wave-tracing apparatus are also provided.

On the first floor are situated the smaller lecture room (seating 70), ordinarily used for class work, and the larger lecture room (seating 150) for combined classes. In the Chemical Building, immediately adjoining, a still larger lecture room (seating 350) is available for meetings and public lectures. All of these rooms are provided with an ample supply of electrical energy of different forms as well as gas, water and other facilities to enable experimental demonstrations to be conveniently and effectively performed. For example, dynamos, motors, and other apparatus of practical size are shown in actual operation to illustrate the lectures, this being made a special feature of the instruction.

The museum contains cases for the collection of apparatus, models, materials etc., relating to electrical engineering. The museum adjoins the lecture rooms so that its contents can be conveniently used for illustration.

On the third floor are located the large instrumental laboratory, the research room, and the studies of the officers. The laboratory contains a number of tables on which the instruments are permanently set up ready for use. These include various forms of galvanometers, ampere balances, standard cells, and resistances; apparatus for measuring inductance, magnetic permeability, hysteresis, and leakage; laboratory standard volt and amperemeters; telegraph, telephone, and electric signaling systems; thermoelectric and electrical heating devices; Röntgen ray apparatus. The research room is used for special post-graduate and thesis work, and is fitted up according to the lines of investigation that are being followed.

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A most important facility is the large and reliable supply of electrical current which is afforded by the central power-plant of the University. This consists of boilers having an aggregate capacity of 2,000 h. p., two low-speed engines directly connected to two dynamos of 275 h. p., each, and two high-speed engines directly connected to two dynamos of 100 h. p. each. This electrical generating plant, having a total capacity of 750 h. p., and illustrating the latest practice in electrical engineering, furnishes current for electric lighting and for driving the motors and fans used in ventilating all of the buildings. Special conductors are also laid to convey to the various laboratories and lecture rooms of the Electrical Engineering Department an ample supply of current for experimental work.

DEPARTMENT OF ARCHITECTURE.

The School of Architecture begins its career in its new quarters with two additional members upon its staff, Mr. William T. Partridge as Lecturer upon Design, and Mr. Henry F. Hornbostel as Assistant in Design. Mr. Partridge, after spending two years in the School of Mines, went to Boston in 1887, where he took the Rotch Travelling Scholarship in Architecture in 1890, which gave him two years of travel and study abroad. Mr. Hornbostel graduated in Architecture in the School of Mines in 1891, and has since spent three years in Paris at the *École des Beaux-Arts*. Mr. Partridge has in charge the second and third year Drawing and Design and Mr. Hornbostel the Design of the fourth year, both under Professor Hamlin's immediate direction.

The only change in the work of the school which the change of site has made, is the lengthening of the morning session from three hours to four and shortening the afternoon session from three hours to two and a half, with an hour for lunch between. The first hour in the morning is given to free-hand drawing. This change was made so that students who live so far away that they cannot reach the school until ten o'clock may not miss a lecture or recitation. But this morning hour proves a desirable thing in itself. The drawing exercise is a delightful thing to begin the day with, and it affords opportunities for a variety of useful exercises which hitherto there has been no time for without spoiling an afternoon.

The rare casts from the Villa Madama presented by Mr. McKim in 1891, and which have until now been inadequately displayed, appear to great advantage on the east wall of the large drawing room. The other walls are hung with this year's Thesis Drawings, which it is proposed to keep on view until they are next year replaced by next year's work. In the corridor are hung the collection of drawings made in the *École des Beaux-Arts* belonging to the school. Beneath them is a vacant space in which it is intended to display, week by week, the current work of the different classes.

DEPARTMENT OF GEOLOGY.

The staff in the Geological department has been engaged in various lines of work during the vacation. Mr. van Ingen left with the summer school about June 1. Taking a night train on the N. Y. Central R. R., the party awakened the next morning in Little Falls, just east of Utica. The lo-

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cality is a famous one in geology, because far to the south of the Adirondack area of the Archean crystalline rocks, a great fault has lifted them again so near the surface on one side of the crack, that the mantle of Paleozoic strata has been sufficiently eroded to expose the gneisses. Starting from these latter as a base the class passed upward across the Potsdam, Calciferous and Trenton formations, to the Utica slate. The narrow gorge of the Mohawk and the glacial phenomena likewise received attention. An evening's ride brought them for the following day to Rochester, where, beginning on the Medina sandstone, they studied the geological section upward to the middle Devonian, as exposed in the Genesee Valley. The second day they visited fossiliferous beds, where good trilobites and other forms could be had in endless quantity. After the Rochester stop of two days, a day was spent at Niagara Falls, and then a long railway ride was undertaken to Marquette. At Marquette the geological scene was an abrupt transformation.

Igneous rocks claimed attention instead of sediments. The peridotite at Presqu' Isle, the altered tuffs, quartz-porphyries, and quartz-diabases of Lighthouse Point, and the interesting relations of the peridotite to the sandstone gave valuable experience. Later at Ishpeming successive excursions were taken across the trough of the Marquette range to the north, and to the south, and along the axis to the west, well up into the upper Marquette strata. A day on the surface around the mines closed the work and the class passed to Professor Peele. Mr. van Ingen did some collecting for the department on his return trip, in Illinois, Indiana, Ohio and New York. He then devoted himself assiduously to the oversight of the removal, and to his care is largely due the ability of the department to begin its work, October 4.

Professor Kemp began work July 1, for the U. S. Geological Survey in the Adirondacks of Essex county, continuing the mapping of the previous summer. He was accompanied by Charles Fulton, Mines '97. The Mt. Marcy sheet of the survey was covered and large portions of the Elizabethtown, and Lake Placid quadrangles were gone over. Valuable records were made which will be worked up through the winter. Professor Kemp also had work in charge for the N. Y. State Survey in Warren, Hamilton and Saratoga counties. In this he was assisted by D. H. Newland, lately fellow in geology. Mr. Newland had with him for a month, B. F. Hill, University scholar in geology. This Archean area was traversed and collections and notes were accumulated which will be worked up this winter for a report to the State Geologist. The work was continued by Mr. Newland up to November 1.

Mr. Hollick was one of a party of several geologists that made a critical examination in June of the geological relations of the stone implements in the Trenton gravels, and subsequently reported on his observations at the Detroit meeting of the American Association. He likewise prepared a short report for *Science*, which appeared October 29th. The vexed question which it was hoped this examination by a committee would settle, remains as much a matter of controversy as ever. Later in the summer Mr. Hollick was on Block Island for some weeks, investigating further the interesting question of the age of the local clays, about which there was some difference of opinion, as shown by the scientific journals last year. Much new and important matter was obtained that will be presented to the New York Academy of Sciences the coming winter. Mr.

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Hollick received the degree of Doctor of Philosophy from the Columbian University of Washington, D. C., last June. The dissertations upon which the degree was granted were: Minor I., Botany, *The Anacardiaceæ of North America.* Minor II., Mineralogy, *The Mineralogy of the Serpentine Area of Staten Island, N. Y.* Major, Geology, *The Paleobotany of the Yellow Gravel at Bridgeton, N. J.*

The department is now in full possession of its new quarters in Schermerhorn Hall and rejoicing in the generous space and light. The study collections are in fairly good order and the laboratory is a most convenient and attractive place wherein to work. Dr. Julien has begun his new duties with the department and has generously and elaborately increased its rock collections from his own gatherings of earlier years. They now furnish admirable materials with which to study and illustrate petrography. J. D. Irving, fellow-elect in geology, has been engaged during the summer with the U. S. Geological Survey party under Dr. Whitman Cross in the La Plata Mountains of southwestern Colorado. On his return he did some collecting for the department on the Spanish Peaks. The department has also received very acceptable additions to its rock collections, through the kindness of A. C. Beatty and G. Sessinghouse, during a western trip, taken the past summer.

A most acceptable gift has also recently come from Mr. J. S. Curtis, formerly of the U. S. Geological Survey, whose monograph on the mines at Eureka, Nevada, is familiar to all students of geology. Mr. Curtis has been successfully engaged in mining in South Africa of recent years, and has been so kind as to send the geological department a very complete set of specimens, illustrating each productive reef near Johannesburg. This opportunity of expressing our appreciation and thanks is gladly taken.

DEPARTMENT OF PHYSICS.

Naturally the Department of Physics has shared in the general improvement of building and location which has come to the whole University. At present it occupies the lower four floors of the building to which it gives a name and which it will ultimately occupy exclusively. Some few rooms are reserved for janitors, store-room, and other administrative uses. Nothing has been overlooked in the endeavor to make this a complete establishment for instruction in physics as well as for original research. It is hoped that it will soon be possible to print a rather full description of these laboratories, pointing out the thoroughness of their construction and equipment, together with certain special details. The instrumental equipment of the laboratory remains practically the same, and, although it is sufficient for the absolute necessities of instruction, still it would be a great advantage if even a few thousand dollars could be expended on some new and much needed instruments.

The staff of instructors has been increased by the appointment of two new assistants, making a present total of twelve. When it is remembered that all the subjects usually treated as mathematical physics are here given under the "department of mechanics" and that all the subject of applied electricity is given under "electrical engineering," it will become evident that at least in the numbers of instructors and courses, Columbia is second to none in what is usually broadly called physics. The new assist-

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ants are Dr. F. L. Tufts, who took his Ph.D. here last spring; and Dr. W. S. Day, who took his Ph.D. at Johns Hopkins in the early summer.

Two new courses will be given this winter; one by Mr. Gordon on elementary meteorology and one on general physics for students in medicine by Mr. Hallock.

With the improved opportunities offered by additional rooms, especial attention will be given to the development and perfecting of special laboratory courses in advanced work for graduate students who may have already had considerable laboratory experience.

BOOK REVIEWS.

Glaciers of North America. A reading lesson for students of geography and geology. By ISRAEL C. RUSSELL. Boston, Ginn & Co. 1897. Pp. iv+207. Plates I–XXII. Figures 1–10. Price, $1.90.

Volcanoes of North America. A reading lesson for students of geography and geology. By ISRAEL C. RUSSELL. New York, The Macmillan Co. 1897. Pp. vii+346. Plates I–XVI; figs. 1–11. Price, $4.00.

Professor Russell's "Lakes of North America" has now been followed by the two further books cited above. They mark the growing interest in those themes that lie along the border line between geography and geology, and that enthusiastic disciples of the "new geography" have formed into a special field of research. Interest in these attractive subjects is always to be cultivated by all students and teachers, whether of geology or geography, and all will welcome effort in these directions when wisely made. Professor Russell's books will be of great service to science, because, with exceptional felicity of style and treatment, they set forth the subject in a way, which, while not too abstruse for the general reader, yet suggests much that is modern and up-to-date to the professional teacher. To the latter, whether in school or college, they will furnish a resumé of the general theories of lakes, glaciers and volcanoes, as well as much illustrative material from the continent on which we live.

The volume on glaciers establishes at the outset three types, the *Alpine*, which is found on mountain tops and in mountain valleys; the *Piedmont*, which, coming down from off the mountainous region, spreads out fan-like on a plain, before disappearing; and the *Continental*, which covers vast areas, more or less regardlessly of minor topography, as in Greenland to-day, or as in North America during the Glacial Period. Having established the large types, the author discusses next the minor features, such as moraines, crevasses, bergschrunds, glacial streams, glacial abrasion, glaciated surfaces, glacial deposits and the changes brought about in topography. These last named are, of course, of wonderful significance in our Northern States, where the relief of the land is so largely the result of the great ice sheet, and while Professor Russell confines himself pretty closely to modern glaciers, what he says cannot but have significance in connection with the greater glacier of the past.

In the subsequent chapters our author describes in order the glaciers of the Sierra Nevada and of the Cascades, and many readers will be surprised to learn of their size and extent in the great volcanic peaks along the Pacific in Washington, Canada and Alaska. His pages on the last named

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are of special interest from his own well-known and courageous explanations among them. For some years past the central points of glacial study have been changing from their old-time location in the Alps to Alaska and Greenland. The large scale on which the phenomena can be observed in the polar regions of North America place them in the foreground of modern science and lend peculiar importance to them in books for students.

Chapter VII. is devoted to the continental glacier of Greenland and the Arctic region. Chapter VIII. takes up the climatic changes that are indicated by the glaciers of North America, their present recession, and earlier advance, and certain theoretical considerations, such as the influence of débris upon movement. Chapter IX. gives an excellent, brief statement and review of the various explanations that have been advanced to account for glacial movement, viz: the "sliding hypothesis;" the hypothesis of "dilatation;" the hypothesis of "plasticity;" the hypothesis of "regelation;" the hypothesis of "expansion and contraction;" the hypothesis of "liquefaction under pressure;" the hypothesis of "molecular change;" and the hypothesis of "granular change." A mere catalogue of these shows what an obscure question the movement of a glacier is, and what a number of causes may enter into it. From the above an eclectic hypothesis is framed that admits the importance of one view and another, and makes the final movement a function of a number of variables.

A chapter on the life history of a glacier closes the very suggestive and interesting volume.

The volume on "Volcanoes" is sumptuously printed, on heavy paper and in Macmillan's best style. It is a happy coincidence that it appears at the same time with Sir Archibald Geikie's great work on the "Ancient Volcanoes of Northwestern Europe" so that data upon volcanic phenomena on both sides of the ocean are now easily accessible.

Professor Russell devotes more than one-third of the book (126 pp.) to Chapter I., which is an introductory exposition of the general phenomena of volcanoes. He establishes at the outset several types, viz: Stromboli, a continuously but moderately active vent; Vesuvius, an intermittent, but, when active, a violent vent; Krakatoa, an enormously explosive centre, producing little or no fluid lava; the Hawaiian volcanoes, with vast but relatively quiet floods of lava; the fissure eruptions of the past as illustrated by the Deccan trap sheets of India; the Columbia lava fields of our northwest; and, finally, the buried sheets and dikes of the so-called "Newark" system, the Jura-Triassic belt of eastern North America. The stages in the lives of volcanoes are next outlined, viz: the eruptive, the fumarole, the solfatara and the hot spring or geyser stages. The products of eruptions follow, embracing gases, vapors and rocks and then the interesting forms assumed by lava, which are best described by the curious Hawaiian words, such as "aa," for the jagged and rough surfaces produced by the piling up of broken crusts on a still moving stream; and "pahoehoe," or the fluted surface assumed by a slowly moving, wrinkling and chilling flow. The characteristics of the bottoms of sheets and the crystalline structure of the central portions receive attention and then fragmental deposits, driblet cones, Pele's hair, volcanic bombs, scoria cones, and sheets of volcanic sand and dust.

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Passing to larger topics, the profiles of volcanic mountains are discussed and then the various types of cones, such as mountains formed of lava sheets, cones formed of projectiles, composite cones and also dikes and necks. The interesting wrecks of former greatness represented by eroded, volcanic centers, receive attention, as well as the plutonic phenomena presented by subterranean intrusions, such as dikes, sheets, plugs, laccolites, subtuberant mountains, with generalizations based on these. A brief review of the characters and common kinds of igneous rocks closes the chapter.

Chapter II. really begins the subject-matter proper of the book. Professor Russell embraces Central America in the general term North America, but sets aside Iceland as more intimately connected with northwestern Europe, and the West Indies on account of their close relations with South America. The chief location of volcanoes, past and present, in the Cordilleran belt of North America is made apparent, and the following broad grouping is established as the plan of the subsequent treatment:

1. The Central American and Mexican regions of active craters.

2. The middle region of extinct or perhaps, in part, dormant volcanoes, extending from central Mexico through the western part of the United States and far into Canada.

3. The Alaskan region of still steaming volcanoes, Chapter III. gives some interesting statistics and details of the cones; in the first division 66 are cited, of which 12 are active, 19 are quiescent, 33 are extinct and the state of 2 is questionable. Several have been formed within historic times, of which Izulco, 1770, in San Salvador, and Jorullo, 1759, Mexico, are the most interesting. In Chapter IV. the lofty cones of Mexico are described, and in Chapter V. the wonderfully well preserved and striking cones of our western States and of Canada. This chapter impresses us as the most interesting of the book, and readers not already familiar with the West, will be surprised to find the perfection of volcanic form that is still preserved there. The great volcanic peaks along the northwest coast yield to none in impressive character.

Chapter VI. treats of the deposition of volcanic dust, and Chapter VIII. reviews the theoretical considerations regarding the cause of volcanic eruptions. Our author argues against steam as a cause and in favor of it as an attendant on eruptions, a position which many will dispute. The book closes with a sketch of the life history of a volcanic mountain.

Professor Russell's work will prove interesting and instructive reading to a wide circle and will materially aid the spread of sound information on the subjects treated. As collateral reading, to courses in geology, all his books will find a field of usefulness and among general readers they should receive a warm welcome. J. F. K.

Fuel and Refractory Materials. By A. HUMBOLDT SEXTON. Blackie & Son, London; and D. Van Nostrand Company. New York. 1897. Price, $2.00.

This little volume is intended merely for student use, going more deeply into the subject than the general manuals of metallurgy.

It was the aim of the author to present a work concise and comprehensive in character, which could not only be used as a text-book, but would afford to engineers and metallurgists a ready means of obtaining a good general idea of the subjects treated, and as such the author's efforts may be regarded as successful.

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The work deals mainly with fuel and its application, the section devoted to refractory materials occupying a relatively small space.

The subject-matter is discussed under the following heads, viz: Chapter I., Combustion. II., Heating power of fuels. III., Fuels—Wood, Peat and Charcoal. IV., Solid Prepared Fuels—Charcoal Peat, Charcoal, Coke. V., Coal Washing. VI., Liquid Fuels. VII., Gaseous Fuels. VIII., Recovery of bi-products. IX., Furnaces for Metallurgical Purposes. X., Supply of Air to the Furnace—Removal of Waste Products. XI., Pyrometry. XII., Calormetry. XIII., Utilization of Fuel. XIV., Testing Fuels. XV., Refractory Materials—Bricks, Crucibles. References and Index.

The work is well illustrated by 104 cuts and is of excellent quality of paper and typography. It is bound in board covers and comprises 343 pages and index. J. S.

The Stamp Milling of Gold Ores. By T. A. RICKARD. The Scientific Publishing Company. New York and London. Pp. 260; illustrated. Price, $2.50.

This subject, even interesting by reason of the diversity of ores treated and consequent variations of practice, is well described by the author, to whom praise is due for the comprehensive compilation of results. Much of the work has already appeared in the *Engineering and Mining Journal* and *The Mineral Industry*, the present treatise being an elaboration of these articles. The subject-matter is mainly descriptive of practice, still much is given of distinct bearing on the chemistry and mechanics of the process.

The work includes the description of the milling practice in Gilpin county, Colo.; the Black Hills, S. Dak., and the Northern Lode in California. Foreign practice comprises the process as employed at Clunes, Ballarat and Bendigo in Australia, and the Thames and Otago districts in New Zealand. It is to be regretted that the practice of the Witwatersrand district in South Africa is not included.

The subjects of mill design, machinery, operation, feeding, batteries, screens, care of plates, etc., are discussed in a practical manner. Special attention is called to the subjects of costs of milling, life of machinery and percentage of salvage. These are analyzed and compared by districts and the cause of difference discussed.

The designs of stamp mills and machinery are well illustrated by detailed drawings, sketches and reproductions from photographs. The book is well printed and bound in conformity with the other publications of the Scientific Publishing Company. J. S.

The Alternating Current Circuit. By W. PERREN MAYCOCK. The Macmillan Company. Pp. 102. 51 illustrations and ruled pages for notes. Price $1.00.

In this little book the author attempts to present the various phenomena accompanying an ordinary or single-phase alternating current and to explain them without the use of mathematics. Adopting "the surplus and deficit theory" of electricity as a foundation he describes and discusses the fundamental phenomena by the aid of mechanical analogies.

This method, is, however, open to two objections: (1) Analogies are not very convincing proofs, as the student is unable to judge whether they are good ones or not; (2) analogies ought not be carried too far, and

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very often are extremely poor explanations, as the author himself admits, for he says in regard to his own explanation of wattless current on page 92: "The above explanation is rather weak, but is perhaps better than none at all; for at all costs the reader must get some idea, however vague, that a more or less wattless current can exist.

The book is, however, a correct statement of the phenomena, and the analogies selected as explanations are very ingenious and well taken.

W. H. F.

Manual of Qualitative Chemical Analysis. By the late DR. C. REMIGIUS FRESENIUS. Translated from the sixteenth German edition, by Horace L. Wells, M.A. John Wiley & Sons, N. Y. Pp. 764. 8vo. Price, $5.00.

Fresenius manual has so long been a familiar text-book for students in qualitative analysis that a discussion of its merits would be superfluous.

The new edition, while identical with the preceding in arrangement and treatment of the subject, contains much valuable new material which adds 250 pages to the book. The translator claims no responsibility except for formulæ and nomenclature, so the present edition represents an almost literal translation of the latest German edition.

Among many additions and improvements the following are of importance. New reagents, such as hydrogen peroxide, diphenylamine, paratohudine, etc., are used. In Section III. of Part I., which contains the qualitative tests for the bases and acids, the increase is over one hundred pages, much of which is devoted to the rarer elements. Tests for germanium and for salysilic acid are found here for the first time. Under the part devoted to the alkaloids cocaine and some new tests have received recognition.

One feature of the present work which deserves special mention is the presence of numerous references to journals. This is a most excellent innovation, and would be even better were the other journals referred to as often as the Zeitschrift für Analytische Chemie.

Some few formulæ may be criticized; for example, we have considered lime as CaO not $Ca(OH)_2$ and sodium tetraborate without water of crystallization is not usually termed borax; there is also good ground for writing potassium sulphocyanide KSCN instead of KCNS. But as a whole the book is most valuable, both as a text book for students who intend to pursue a thorough course in qualitative analysis and as a book of reference and the translator is to be congratulated on performing so well a most arduous task.

E. H. M.

The Mineral Industry, Its Statistics, Technology and Trade in the United States and other Countries to the end of 1896. Vol. V. Being the statistical supplement of the *Engineering and Mining Journal.* Edited by RICHARD P. ROTHWELL. Published by the Scientific Publishing Co., of New York. 8vo. 865 pp. Board covers. Price, $5.00.

This work, which appears anually from the press of the Scientific Publishing Company, has already earned for itself a prominent place in the technical literature of the day. The vast amount of detail relative to the statistics and production of the various metals and minerals needs a master mind to properly arrange so as to be of ready value to the reader, and the editor deserves great praise for the able and painstaking manner in which these facts have been collated.

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This volume follows the general plan of its predecessors, introducing mongraphs by competent specialists in the different chapters bearing on the subjects. Among the more important may be quoted: "Cement Manufacture in Great Britain," by W. H. Slanger and Bertram Blount; "Progress in Electro-Chemistry and Electro-Metallurgy," by W. Borchers; "Modern Coke Ovens and their By-Products," by George Lunge; "The Present Development of the Barrel Chlormation Process," by John E. Rothwell; "Chloridizing Roasting of Calcareous Silver Ore containing Arsenic in Large Quantities," by Ottakar Hofmann; "Hydro-Metallurgy of the Precious Metals," by Henry Wurtz; "Manufacture of Basic Iron in Alabama," by W. Phillips; "Recent Improvement in Lead Metallurgy," by H. O. Hofman; "The Rare Elements," by L. M. Dennis; "Metallurgy of Tin," by Henry Lewis; "The Treatment of Zinc-Lead Sulphide Ores," by F. L. Bartlett; "The Diffusion of Metals," by W. C. Roberts-Austen; "The Micrographic Analysis of Metals," by J. O. Arnold; "Progress in Ore Dressing in 1896," by Robert H. Richards.

This volume supplements and increases the vast amount of valuable information appearing in Vols. I., II., III. and IV., and with them forms a collection of statistics of history, occurrence, methods of mining, treatment of ores, costs, uses, prices current, etc., of great value to the chemist, engineer, metallurgist and all interested in the development of the mineral production of the country. J. S.

Notes on Lead and Copper Smelting and Copper Converting. By HIRAM W. HIXON. Scientific Publishing Company. New York. 8vo. 116 pp. Board covers. Price, $3.00.

As the author states in his preface, this book is a series of notes on the practical work of lead and copper smelting, including the converting of copper matte. The subject-matter is treated in a clear manner and supplemented with excellent illustrations, many of which are dimensioned working drawings. The work concludes with the specifications of buildings and machinery for the copper converting plant of the Anaconda Minining Company at Anaconda, Mont., with accompanying working drawings.

A summary of the chapters will best show the contents and extent of the work. Chapter I., Copper Matte Smelting. II., Extraction of Gold and Silver from Matte. III., The Calculation of Furnace Charges. IV., Types of Furnaces. V., Spouts, Settlers and Jackets. VI., Blowing in and Barring down a Furnace. VII., Handling Blast Furnace Slag. VIII., Design of Lead Blast Furnaces. IX., Lead Slags and Losses in Lead Smelting. X., Improvements in Roasting Furnaces. XI., Smelting Raw Concentrates with Hot Blast at Anaconda. XII., Copper Converting at Anaconda. XIII., Blowing a Converter Charge. XIV., Design of Converted Plants. XV., Lining a Converter. XVI., Casting Anodes direct from Converter. XVII., Cost of Producing Copper at Anaconda. Appendix, Specifications of Buildings and Machinenry for the Anaconda Copper Converting Plant, with a set of eighteen detailed working drawings.

While the author's discussions are very general in character and limited in extent, the work contains much of modern practice and should be of value to all interested in the metallurgy of lead and copper.

J. S.

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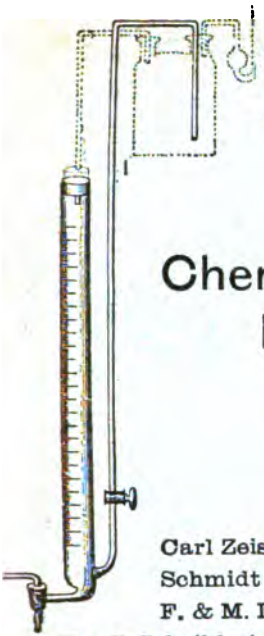

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CONTENTS:

An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D..... 113
The Cleps-Tachymeters. By C. McK. Lewis..... 150
Electrical Engineering at Columbia University. By Francis B. Crocker. 175
A Straight Line Formula for Cast-Iron Columns. By Samuel Osgood Miller. 185
System in the Location of Mining Districts: By Theo. F. Van Wagenen, E.M. 189
Physical Tests of New York Shales. By Heinrich Ries, Ph.D..... 192
The Fan Pump—A Special Instance of its use for Mill Water Supply. By F. C. Hooper, Met.E..... 194
The Condition in which Zinc Exists in Slag. By Malvern Wells Iles... 197
Power Consumption on the Lenox Avenue Conduit Electric Road, New York City. By G. F. Sever..... 200
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph.D..... 209
Alumni and University News..... 219
Book Reviews..... 223

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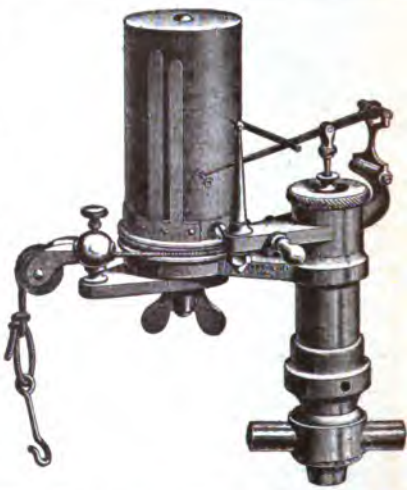

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VOL. XIX. JANUARY, 1898. NO. 2.

AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

BY ALFRED J. MOSES, PH.D.

(Continued from page 35, Vol. XIX.)

PART II. THE OPTICAL CHARACTERS.

LIGHT RAYS.

In any homogeneous medium light is transmitted in straight lines, which are here called *light rays*, by vibrations of the particles of an imponderable light ether which fills all space even between the particles of solids, and it is probable that in common light the path of any vibrating ether particle is an ellipse constantly altering in shape and position but always remaining in the same plane.

The time of a complete vibration is called a PERIOD, the advance during a period is called a WAVE-LENGTH and determines the color of the light, and the AMPLITUDE of the vibration determines the intensity of the light.

RAY SURFACES.*

If we assume one vibration of a luminous point within a homogeneous material this motion will be transmitted along rays in all directions. At the end of any definite time along each ray the motion will have just reached a certain point. The closed surface

* L. Fletcher, Optical Indicatrix, *Mineral Mag.*, IX., 291.

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through these points is called the ray surface of the substance. It is coincident with the wave surface but obtained in a different manner.

RAY FRONT AND FRONT NORMAL.

The plane front of an extremely small pencil of rays including the given ray will be coincident with the plane tangent to the ray surface at the extremity of the ray and may be called the ray front. It is in general oblique to the ray. The direction normal to the ray front may be called the front normal.

CHAPTER VII.

THE OPTICALLY ISOTROPIC CRYSTALS.

Any homogeneous isometric crystal will show the same optical properties in all directions, that is, will be optically *isotropic*.

I. OPTICALLY ISOTROPIC CRYSTALS WHICH ARE SINGLY REFRACTING.

RAY SURFACE.

The velocity of transmission of light is constant in all directions, that is the ray surface is always a sphere, all diametral planes are planes of symmetry and all diameters are axes of isotropy.

In different substances, however, the velocities are different, that is for the unit of time with light of the same wave-length the spherical ray surfaces are of different diameters.

In the same crystal the shorter the wave-length of the light the slower the velocity of transmission; that is, for instance, for the unit of time the ray surface for violet light will be smaller than for red light.

INDEX OF REFRACTION.

The differences in the ray surfaces are determined by measuring the amount a light ray is bent or refracted on entering a crystal; the ratio of the velocities of the incident and refracted rays or so-called "index of refraction" being equal to the ratio of the sines of the angles of incidence and refraction.

Let *IO*, Fig. 208, be a ray of light striking the crystal face *AB* at *O*. Let M_2 be the ray surface of the crystal, M_1 that of the

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outer medium described around the point of incidence for a unit of time. The ray front in the first medium at the expiration of this time would be TE, E being a point of the front just impinging

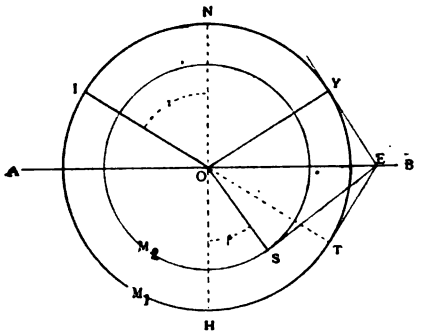

FIG. 208.

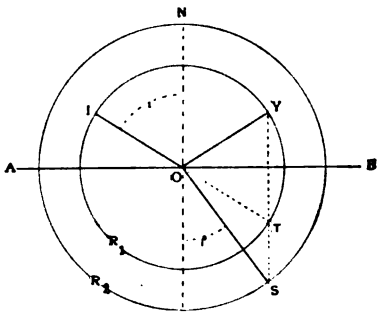

FIG. 209.

on AB, therefore also a point of the new ray front, that is of the tangent plane ES. The refracted ray is therefore * OS to the point of tangency. OY is the corresponding reflected ray.

In the triangles OET and OES, Fig. 208,

$$OE = \frac{OT}{\sin OET} = \frac{v_1}{\sin i} \text{ and } OE = \frac{OS}{\sin OES} = \frac{v_2}{\sin \rho}$$

hence,

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin \rho}$$

Usually the ratio recorded is that of the crystal with respect to air. Denoting the velocity in air by v and the indices of the outer medium and crystal with respect to air by n_1 and n, we have

$$n_1 = \frac{v}{v_1} \text{ and } n = \frac{v}{v_2}$$

and substituting these values we have

$$n = n_1 \frac{\sin i}{\sin \rho}$$

There is no *refraction for normal incidence*, for $\sin i = 0$, hence

* This is called the Huyghens construction, each point of the border surface becoming a new center of propagation of light. A still simpler construction is that of Snellius, Fig. 209, R_1, is a sphere with radius the index of refraction of outer medium R_2, a sphere with index of crystal. Prolong IO to T. Draw TS parallel the normal ON, then is OS the refracted ray, and OY the corresponding reflected ray.

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$$n = \frac{0}{\sin \rho}$$

which is only possible if $\rho = 0$.

With a *plane-parallel plate* the ray emerging is parallel to the entering ray, for at entrance, Fig. 210,

$$n = n_1 \frac{\sin i}{\sin \rho} \text{ and at emergence } n_1 = n \frac{\sin i_1}{\sin \rho_1}$$

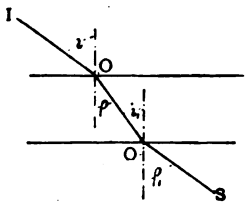

FIG. 210.

whence $$\frac{n}{n_1} = \frac{\sin i}{\sin \rho} = \frac{\sin \rho_1}{\sin i_1}$$

but $i_1 = \rho$ hence $i = \rho_1$

An approximate determination of the index of refraction may be made by measuring the displacement of the focal distance of a microscope caused by the interposition of a known thickness of crystal as described, p. 148, but usually one of the following methods will be employed.

Determination of Index of Refraction by Prism Method.

Let *AOC*, Fig. 211, be the section of the prism at right angles to the refracting edge *O*. About *O* describe the circles R_1 and R_2 with radii proportionate to the indices of refraction of the outer medium and prism respectively. Let *IO* be the incident ray, then, by the construction of Snellins (foot note p 115), is *OS* the direction of the ray in the prism. From *S* draw *SP* normal to the surface *CO*, then is *OP* the direction of the ray on emergence. Denoting the prism angle by $\chi = NON^1$ the total deviation by $\delta = TOP$, the incident angle by $i = TON$, and the angle of refraction at the second surface by $\rho_1 = PON^1$.

$$\delta + \chi = TOP + NON^1 = 2\,TOP + PON + TON^1,$$
$$i + \rho_1 = TON + PON^1 = 2\,TOP + PON + TON^1$$

hence,

$$\delta + \chi = i + \rho_1 \text{ or } \delta = i + \rho_1 - \chi.$$

This value of δ is least* when $i = \rho_1$, then $\delta = 2i - \chi$ $i = \frac{\delta + \chi}{2}$

* The arc *TP* or δ, Fig. 211, cut by *SP* and *ST*, is least when they make equal angles with *OS* that is when the first deviation $i - \rho$ equals the second $\rho_1 - i_1$ for with any other position of *IO* the point *T* moves a certain number of degrees and one of the arms *TS* or *PS* approaches *OS*, becoming less oblique and cutting off a part of *TP*, the other recedes becoming more oblique and adding a larger arc to *TR*, hence the combined change yielding a larger value for δ.

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when $i = \rho_1$ the ray RS, Fig. 212, within the prism must be normal to BD, the bisectrix of the refracting angle, therefore will $NRS = ABD$ or $\rho = \frac{1}{2}\chi$. Hence substituting in the formula for index of refraction $n = n_1 \frac{\sin i}{\sin \rho}$, we have,

$$n = n_1 \frac{\sin \frac{1}{2}(\delta + \chi)}{\sin \frac{1}{2}\chi}.$$

PRACTICAL MANIPULATION.—Two perfect faces of a clear transparent crystal are required, making such an angle (40° to 70°) with each other that *at the second surface* the ray is incident at less than the angle of total reflection, p. 118 or with a larger angle, the prism may be immersed in a strongly refracting liquid in a parallel walled glass vessel. If necessary, faces may be ground at the proper angles. The other faces of the crystal should be coated with lamp black.

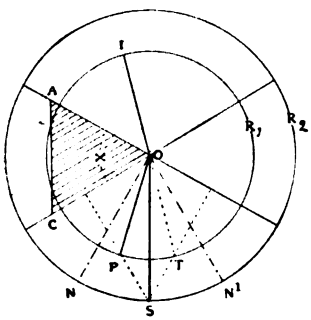

FIG. 211.

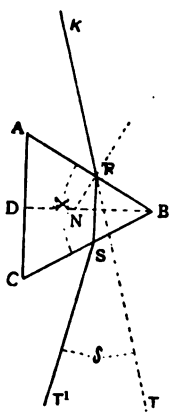

FIG. 212.

The most satisfactory instrument is a goniometer with vertical axis see p. 18–25. The angle χ is centred and measured as described, p. 21. The telescope is then clamped at T, Fig. 212, directly opposite the collimator K and a reading made, the crystal is moved by the centring screws so that the edge B is a little beyond the centre, and, the telescope and graduated circle remaining clamped, is revolved into for example the position shown in the figure. The telescope is then unclamped and turned towards the left until the image is in the field. The crystal is turned towards the right and if the image moves it is recentred by a movement of the telescope towards the right, and this double motion is continued until

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the image appears for a moment to be stationary and then starts to move in the opposite direction.

The position of rest T' the positionis of least deviation and $TT' = \delta$

Monochromatic light* is essential.

If the instrument used does not permit of independent rotation of the crystal the position of minimum deviation and the reading T' are obtained by alternate movements of the telescope and divided circle and the reading of the collimator or T is obtained last.

Determination of Index of Refraction by Total Reflection.

When the index of refraction n_1 of the outer medium is greater than n of the crystal there is a so-called "critical" angle of incidence for which the angle of refraction is 90°; that is, the refracted ray travels along the border surface.

If $\rho = 90°$, $\sin \rho = 1$; hence, $n = n_1 \sin i$ or $\sin i = \frac{n}{n_1}$.

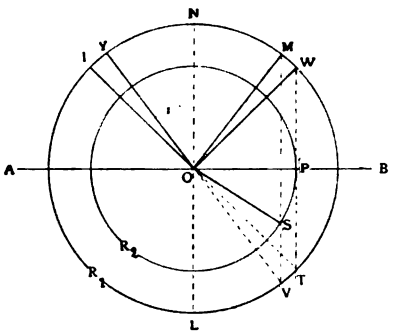

FIG. 213.

For any angle of incidence greater than this the light is totally reflected.

The following is the construction of Snellius: If AB, Fig. 213, is the border surface, R_1 and R_2 circles with radii proportionate to the indices of refraction of the first and second substances, then for the critical angle the direction of the refracted ray must be OP and from the tangent at P results the direction IOT of the limit incident ray.

* Certain solids vaporized in the flame of a Bunsen burner emit light essentially monochromatic. Three very commonly used are RED $\lambda = 0.000670$ Lithium sulphate, YELLOW $\lambda = 0.000589$ Sodium sulphate, Green $\lambda = 0.000535$ Thallium sulphate. Purer light may be obtained by using portion of a spectrum. A. E. Tutton describes an instrument for thus producing light of any desired wave length of greater brilliancy than that yielded by colored flame. *Proc. Royal Soc.* 1894, v. 55, p 111.

The production of monochromatic light by absorption of the other colors is not possible. Blue cobalt glass permits to pass only blue and extreme red. Certain solutions absorb certain rays; aniline blue absorbs yellow; permanganate of potash, green; sulphate of copper, red; chromate of potash, blue. The light passed through a series of these may become essentially monochromatic, *e. g.*, Sulphate of copper, aniline blue and chromate of potash, leave green.

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According to the relative position of the observation telescope and the incident light two different results are obtained.

1°. Total Reflection Proper. If diffused light is admitted in the quadrant *AN*, Fig. 213, and the telescope axis is in the direction *OW*, all rays incident at less than the critical angle are in part reflected, *e. g.*, *OY* along *OM* and in part penetrate the crystal; while all rays incident at more than the critical angle are entirely reflected; that is, the telescope field receives on one half totally reflected rays, on the other partially reflected rays; between these is a sharp line, Fig. 214, which is the intersection of the focal plane of the telescope with a limit surface or cone the vertex of which is at *O* and the elements of which make the critical angle with the normal to the reflecting surface. This limit line is a curve, but within the limits of the field of the telescope is essentially straight.

Fig. 214.

2. Grazing Incidence, or Observation of Transmitted Light.* If the light is shifted to the quadrant *AL*, or, which is equivalent, the light remains in *AN* and the telescope axis is made to coincide with *OT* and the transmitted rays are viewed, then, assuming the faces at entrance and emergence to be parallel, the incident and emerging rays are parallel. All rays incident at less than the critical angle are partially transmitted, but all of greater angle are totally reflected at the first surface; the telescope field is on that side dark, Fig. 215, but on the other side is illuminated by the rays incident at less than the critical angle.

Fig. 215.

In the Kohlrausch apparatus the substance is supported in a liquid of higher index of refraction than the crystal, in such a way that the reflecting surface is vertical and the crystals can be rotated about a vertical line in the reflecting surface. The crystal holder may be simply a metal plate with a window-like opening bisected by a platinum wire and adjusted once for all so that the back surface is in the desired position of the reflecting face and the wire coincides with the vertical cross-hair of the telescope. It is only necessary with this to fasten the crystal face over the win-

* Apparatus for observation of the transmitted ray with liquids were constructed by Christiansen, *Pogg. Ann.*, 1871, 143, p. 250 and others; and for solids by Quinke *Zeit. f. Kryst.*, 1879, 4, 540.

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dow. A more elaborate holder permits rotation of the crystal in its own plane and other adjustments.

The rotation is observed by a horizontal telescope set normal to a plane front of the vessel holding the liquid, that is in direction *TO*, Fig. 216, and the rotation is recorded upon a graduated circle. The best position for the light is found by trial. When the sharp limit line between the totally and partially reflected rays has been made to coincide with the vertical hair of the telescope the light and screen are moved to the opposite side and the plate is rotated until the limit line is again obtained and centered.

Since the angle between the telescope axis and the normal is the critical angle the rotation $NON^1 = 2i$ whence by $n = n_1 \sin i$ the index of the solid results.

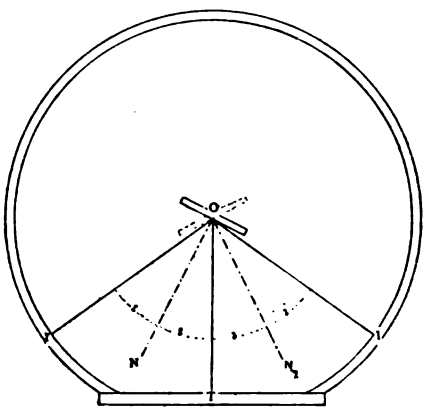

FIG. 216.

A simpler apparatus is made as an attachment to the No. 2 Fuess Goniometer* and is shown in Figs. 217, 218. The pin *a* fits in place of the pin of the usual crystal plate of the instrument; provision for approximate adjustment is made but the accurate adjustments of the Fuess instrument are the principal reliance.

To secure approximately constant temperature the holder is covered by a box of asbestos with proper openings. The mineral is attached to the little plate *f*, and the control mineral at *g*. The rough adjustments are made by the eye, so that the necessary rotation can be secured; then the finer adjustment is made with the Fuess centring screws, and the vessel filled with the refracting liquid. The cover box is then put on, the light adjusted, and the boundary found

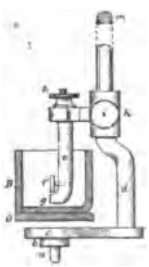

FIG. 217.

FIG. 218.

*A. J. Moses and E. Weinschenk, *Zeit f. Krystallog.*, XXVI., 150 and *S. of M. Quarterly*, XVIII., p 12.

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and centred. After standing, say ½ hour, with light burning, the boundary is recentred and this repeated till no change takes place. The usual readings are then made, after which, without disturbing vessel or cover, the control mineral is raised into the field by the vertical screw and readings obtained from it. From these the index results by the formula

$$n = n' \frac{\sin i}{\sin F},$$

in which

i = half the angle of rotation of the mineral tested.
F = " " " " " " " control mineral.
n' = index of refraction of the control mineral.

These instruments require either monochromatic light, or sunlight may be used if the eye-piece is replaced by a spectroscope, in which case at the proper angle the light of all colors will be totally reflected and the field will show on one side a bright spectrum, on the other a relatively dark spectrum, separated by a line oblique to the vertical hair, Fig. 219. The critical angles corresponding to the Frauenhöfer lines can be successively determined by bringing the points of intersection of these lines with the limit line into contact with the vertical hair.*

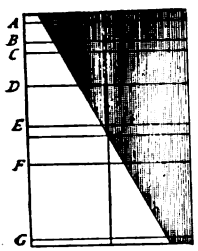

FIG. 219.

The Liebisch apparatus, Fig. 220, employs a glass prism P of high index of refraction, firmly mounted† with the refracting edge vertical and one face normal to the axis of the holder. Diffused monochromatic light is admitted at the side AB, Fig. 221, reflected at the second side BC and emerges at the third side AC.

The edges of the prism are first made vertical; the crystal is then glued to the cap z and adjusted by the screws q so that a collimator signal from the crystal remains fixed in the telescope during a complete rotation by T. By the centring screws $y\ y$ of the goniometer a central line of the crystal is made to coincide with the goniometer axis.

* For a control mineral fluorite is very suitable, as its refraction has been carefully determined, and further, as it is isotropic, has a low index of refraction and is easily obtained.

† As made by Fuess two prisms with indices 1.6497, 1.7849 are furnished.

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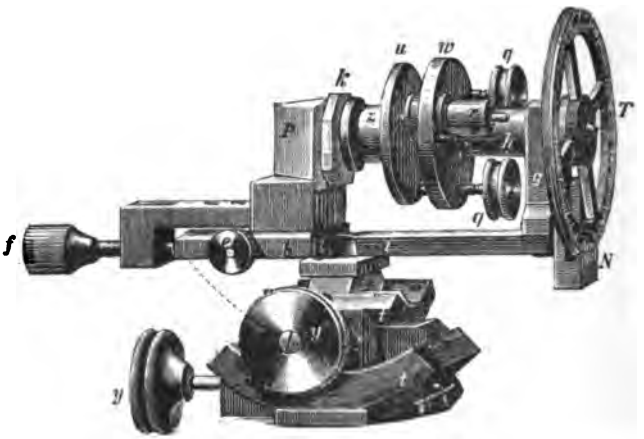

FIG. 220.

The prism is then moved into contact with the crystal, close contact being secured by a drop of strongly refracting liquid.

The determination of the index of the plate requires the measurement of n_1 the index of the prism, of α the refracting angle ACB of the prism, and of δ, the deviation of the emerging ray from the normal to the face of emergence.

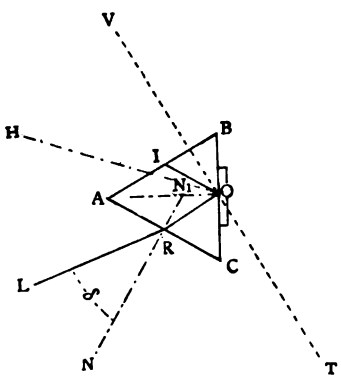

FIG. 221.

To determine δ three readings are needed: *First*, the telescope and collimator are placed opposite each other, say at T and V respectively. *Second*, the telescope is arbitrarily moved to some position L and the carrier turned until the limit line is centred. *Third*, the carrier is turned still further nntil AC gives a signal, that is, until RN bisects LV at OH.

This gives TL, NH, and $HL = \frac{1}{2}(180° - TL)$.

Then the deviation $\delta = LN = NH - HL$.

To find an expression for the index of refraction of the substance:

Since i = critical angle of prism, $n = n_1 \sin i$ (p. 118).

From the figure, $\alpha = ACB = AN_1R = N_1OR + N_1RO = i + \beta$, whence $i = \alpha - \beta$, or in general $i = \alpha \pm \beta$, since as n approaches n_1, β diminishes and may become negative; that is, the ray RL may be on the other side of RN. Substituting, $n = n_1 \sin(\alpha \pm \beta) =$

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$n_1 (\sin \alpha \cos \beta \pm \cos \alpha \sin \beta.)$ The reflected ray OR is refracted at R where $\frac{\sin \beta}{\sin \delta} = \frac{1}{n_1}$, whence

$$\sin \beta = \frac{\sin \delta}{n_1} \text{ and } \cos \beta = \frac{1}{n_1} \sqrt{n_1^2 - \sin^2 \delta}.$$

Substituting,

$$n = \sin \alpha \sqrt{n_1^2 - \sin^2 \delta} \pm \cos \alpha \sin \delta.$$

In the Pulfrich apparatus the glass prism is replaced by a vertical glass cylinder, the substances resting upon the upper base and illuminated from below by diffused light, no light being permitted to enter at the top. The angle δ of deviation from the normal on emergence is measured by a right-angled telescope revolving on a horizontal axis. For this

$$n = \sqrt{n_1^2 - \sin^2 \delta}.$$

In the Abbè apparatus the glass prism is replaced by a hemisphere of glass with the substance resting upon the horizontal base. The critical angle is measured directly by a telescope centred upon the centre of the sphere. For this $n = n_1 \sin i$.

The refracting liquid used may be: Thoulet solution, Rohrbach solution, α mono-Bromnapthalin, Methylene iodide alone or saturated with iodoform or sulphur or any other sufficiently stable and transparent liquid, the index of refraction of which is higher than that of the mineral to be tested.

	Density.	*Temp.*	*Li or B.*	*Na = D.*	*Tl or E.*	*Decrease for 1° increase,*
Glycerine.						
$C_3H_8O_3$	1.2594	20		1.47293		
Thoulet Solution.						
Potassium.	3.122	18	B 1.6960	1.7167	E 1.7391	
Mercury,	2.493	18	B 1.5855	1.6001	E 1.6160	
Iodide.	2.091	18	B 1.5129	1.5235	E 1.5347	
Rohrbach Solution.						
Barium.	3.564	23		1.7931	E 1.8265	
Mercury.						
Iodide.						
Bromnapthalin α.						
$C_{10}H_7Br$.		8		1.66264		.00045 Na
	1.4914	20		1.65820		
Methylene Iodide.						
CH_2I_2		8	Li 1.746	1.7466	Tl 1.7584	.00067 Li .00071 Na
		19		1.7421		.00073 Tl

Saturation with iodoform raises the index about .02 and with sulphur as muchas .04.
Li line is at 32; B at 28. Tl line is at 68; E at 71.

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II. OPTICALLY ISOTROPIC CRYSTALS WHICH ARE CIRCULARLY POLARIZING.

Certain isometric crystals possess the power of rotating the plane of polarization (see p. 128) of the incident light *whatever the direction of transmission;* they are therefore still isotropic, but doubly refracting this rotation having been experimentally proved to be due to two rays transmitted with different velocities and circularly polarized in opposite directions.

RAY SURFACE.

Either circularly polarized ray is transmitted with a constant velocity in any direction, but with respect to each other the velocities have a constant difference, hence the ray surface must be two concentric spheres. Since on reversing any section the direction of observed rotation is not changed it follows that at the extremities of any diameter of the ray surface the rotations in the same shell must be opposite in direction. There can, therefore, be no planes of general symmetry, though every diameter is an axis of isotropy.

The division is, therefore, necessarily limited to classes 28 and 29 which have no planes of symmetry. Examples in class 28 are Barium Nitrate, Sodium Chlorate and Sodium Bromate. The phenomenon has not yet been observed in class 29 and it is evident that the symmetry is not the only determining cause.

The phenomena and testing of circularly polarized light will be described more fully under uniaxial crystals.

ABSORPTION IN ISOTROPIC CRYSTALS.

In optically isotropic crystals monochromatic light diminishes steadily in intensity as the distance traversed increases, but is independent of the direction of transmission.

With white light the different component colors are absorbed at different rates.

For a section of any given thickness therefore of an isometric crystal* the same color tint will be transmitted whatever direction the crystal may be cut.

* The color tints due to the combination of the partially and unequally absorbed rays may vary greatly in specimens of the same substance, which may be properly colorless or faintly colored in ordinary thicknesses and yet frequently occur of brilliant colors, which, nevertheless, conform perfectly in absorption to the crystal symmetry. It is probable that these always contain (dissolved like coloring matter in solution) minute amounts of oxides of rarer metals titanium, zirconium, cerium, etc. See Weinschenk *Zeit. f. Anorg. Chemie, XII.*, 372.

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By decomposing this color with a prism the absorption spectrum is obtained, which usually shows a gradual change in absorption in adjoining portions, perhaps increasing from one end towards the other, perhaps increasing in both directions from the centre. With even a moderate thickness certain colors may be absorbed completely so that the spectrum shows dark bands.

CHAPTER VIII.

THE OPTICALLY UNIAXIAL CRYSTALS.

In every crystal of the hexagonal or tetragonal system the directions equally inclined to the crystallographic axis $\dot{c}$ are optically equivalent, so that c is an axis of isotropy and being a fixed crystallographic direction may be called The Optic Axis.* All diameters normal to $\dot{c}$ are axes of binary symmetry.

III. OPTICALLY UNIAXIAL CRYSTALS IN WHICH THE OPTIC AXIS IS A DIRECTION OF SINGLE REFRACTION.

DOUBLE REFRACTION.

In a moderately thick calcite† cleavage, Fig. 222, mounted with a rhombic face vertical and so that it can be revolved about a hor-

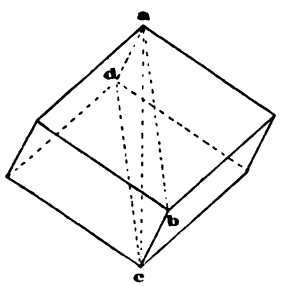

FIG. 222.

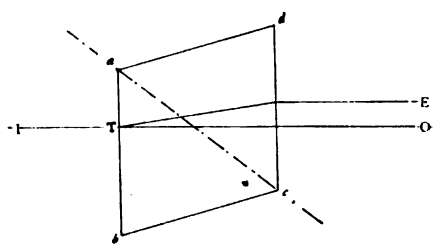

FIG. 223.

izontal axis normal to a vertical face, any light ray, *IT*, normally incident, Fig. 223, at the vertical face, is transmitted in the rhomb as two rays of essentially equal brightness‡ (giving two images of any signal), and as the rhomb is turned about the axis

* It will be seen later that while the optic axis in uniaxial crystals is fixed, the so-called optic axes in biaxial crystals change with the light or by heat or pressure.

† Calcite is chosen because of the marked divergence of the two rays. The discussions, however, are general.

‡ Absorption is more marked in the case of one image than the other.

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one of these remains fixed in position, the other moves around the first and always so that both remain in a plane parallel to *a b c d* (the so-called principal section) and at a constant distance apart.

With crystals optically isotropic and normal incidence the fixed image only would have been seen, hence this is called the *ordinary* and the other by contrast the *extraordinary*.

If a second calcite rhomb similarly mounted is placed in front of the first and revolved, the other remaining stationary, each of the two rays from the first is again split into two rays, an ordinary and an extraordinary ray, lying in the principal section of the second calcite, *which are no longer of equal brightness*, but wax and wane in turn, the sum of their intensities remaining constant.

PLANE OF VIBRATION.

The changes in intensity (brightness) corresponding to different values of α, the angle between the principal sections, correspond exactly to the assumption that the varying elliptical vibrations of common light are converted by the first calcite into two sets of straight-lined vibrations, one parallel to the principal section, one at right angles thereto and, since the rays are of equal intensity, with equal vibration amplitudes.

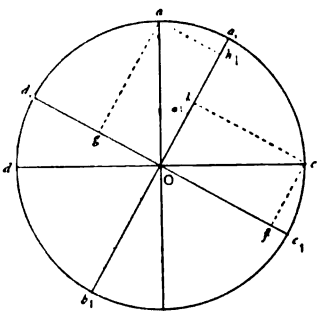

FIG. 224.

Denoting the ordinary and extraordinary rays from the first calcite by O and E and their ordinary and extraordinary components in the second calcite by O_0 O_e and E_0 E_e. It will be seen from Fig. 224.

	Ray.	Direction.	Amplitude.
If the principal section is the plane of vibration of the ORDINARY RAY.	O	ab	$Oa = 1$
	O_0	a_1b_1	$Oh = \cos \alpha$
	O_e	c_1d_1	$Og = \sin \alpha$
	E	cd	$Oc = 1$
	E_0	a_1b_1	$Ok = \sin \alpha$
	E_e	c_1d_1	$Of = \cos \alpha$
If the principal section is the plane of vibration of the EXTRAORDINARY RAY.	O	cd	$Oc = 1$
	O_0	c_1d_1	$Of = \cos \alpha$
	O_e	a_1b_1	$Ok = \sin \alpha$
	E	ab	$Oa = 1$
	E_0	c_1d_1	$Og = \sin \alpha$
	E_e	a_1b_1	$Oh = \cos \alpha$

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Both assumptions give, therefore, the same amplitudes for the four rays, viz: $O_0 = \cos a$, $O_e = \sin a$, $E_0 = \sin a$, $E_e = \cos a$, therefore both correspond to the same relative intensites (proportionate to squares of amplitudes), moreover $O_0 = E_e$ and $O_e = E_0$ for all values of a, and also that $O_0 + O_e = O$ and $E_0 + E_e = E$ for $\sin^2 a + \cos^2 a = 1$.

We shall hereafter assume *that the plane of vibration of the extraordinary ray is parallel to the principal section, and that of the ordinary is at right angles to the principal section.*

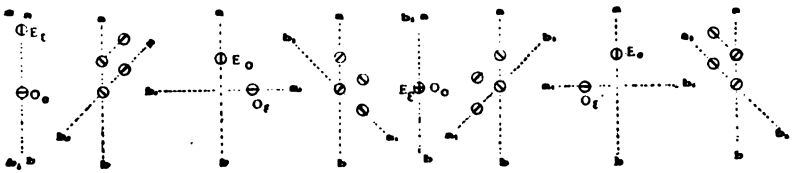

FIG. 225.

The results corresponding to different values for a are illustrated in Fig. 225, a b representing the principal section of the first calcite a_1 b_1 that of the second calcite and the diameter in each circle being the assumed vibration direction. The intensities corresponding are proportionate to the squares of the vibration amplitudes.

Angle	Intensity proportionate to $\cos^2 a$		Intensity proportionate to $\sin^2 a$	
	O_0	E_e	O_e	E_0
0	1	1	0	0
45°	½	½	½	½
90°	0	0	1	1
135°	½	½	½	½
180°	1	1	0	0
225°	½	½	½	½
270°	0	0	1	1
315°	½	½	½	½
60°	¼	¼	¾	¾

That is at zero two rays are extinguished and the same two at 180°. From these points they gradually increase at the expense of the

* This supposition is purely for convenience as best connecting this work with the common usage in "Optical Mineralogy and Petrography." The question is one for the physicists and by them seems to be more generally decided in the other way. See Jas. MacCullagh, *Trans. Royal Irish Soc.*, XVIII., *XXI.*, W. H. C. Bartlett, *Amer. Jour. Science*, Nov., 1890. F. Neumann, *Vorlesungen über der festen Körper und des Lichtäthers.*

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other pair and are at a maximum at 90° and 270°, the others being then totally extinguished. At all diagonal positions there are visible four rays of equal intensity, and for all other positions as at 60° the intensity of two rays are greater than those of the other two.

PLANE OF POLARIZATION.

Common light reflected at a particular angle of incidence characteristic of the reflecting substance acquires the same peculiar characters as the rays produced by double refraction.

If normally incident at a rhombic face of a calcite rhomb an ordinary (unrefracted) image is obtained when the plane of reflection (through incident and reflected ray), is parallel to the principal section of the calcite, an extraordinary when these are at right angles to each other and, for all other angles, both ordinary and extraordinary of varying intensity, just as with calcite.

Malus* described the reflected ray as POLARIZED with reference to the plane of reflection and called the latter the PLANE OF POLARIZATION of the ray.

In the same sense the two rays produced from common light by double refraction in calcite are said to be POLARIZED.

The principal section of the analyzing calcite becomes the plane of reference. *Whatever it is parallel to when a ray undergoes ordinary refraction is the plane of polarization of that ray*; that is, the plane of polarization of the *ordinary ray* is the principal section and the plane of polarization of the *extraordinary ray* is at right angles to the principal section.

RAY SURFACE.

By measurement of the indices of refraction for different directions of transmission it is found:

1°. That the velocity of the ordinary ray is constant.

2°. That the velocity of the extraordinary ray in any section through c varies for different directions of transmission. For the direction parallel to c it is equal to that of the ordinary and differs most for the direction of right angles to c and for any other direction, as discovered by Huyghens for calcite, the velocity is given by the corresponding radius-vector of an ellipse the axes of which are the least and greatest velocities.

The ray surface for light of any wave-length is therefore a double surface, the extraordinary shell being an ellipsoid formed by the

Mem. de la Soc. de Strasbourg, 1811, I., 284.

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revolution of the ellipse, the axes of which are the least and greatest velocities, about one of its axes and the ordinary shell a sphere with a diameter equal to the axis; of revolution of the extraordinary. This surface is symmetrical to all planes through the optic axis and to the diametral plane at right angles thereto.

Denoting the indices of refraction of the fastest and slowest rays that is of the two rays transmitted normal to the optic axis by α and γ and their vibration directions by $\mathfrak{a}$ and $\mathfrak{c}$.* There will be two cases arbitrarily distinguished as POSITIVE in which $\mathfrak{c}$ is parallel the crystallographic axis c and NEGATIVE in which $\mathfrak{a}$ is parallel c. In the former case, therefore, the extraordinary ray with vibration direction parallel c will be the slower ray and the extraordinary shell will be wholly within the ordinary as in Fig. 226, while in the negative surface the extraordinary ray is the faster and the extraordinary shell will enclose the ordinary as in Fig. 227.

THE OPTICAL INDICATRIX.

All the relations between the optical characters of a crystal can be expressed by the geometrical characters of the extraordinary shell or its equivalent,† the ellipsoid of revolution, the axis of revolution of which is the index of refraction of the extraordinary ray transmitted normal to c and the equatorial diameter the index of the ordinary ray.

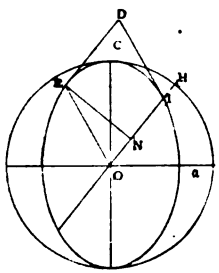

FIG. 226, +, $c = \mathfrak{c}$.

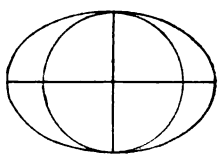

FIG. 227, —, $c = \mathfrak{a}$.

Let IO be any direction of transmission. Draw ID tangent at

* Often called axes of elasticity.

† In indicatrix axis in direction $\mathfrak{a} = \alpha$, in shell $= \frac{1}{\gamma}$. In indicatrix axis in direction $\mathfrak{c} = \gamma$, in shell $= \frac{1}{\alpha}$. But $\alpha : \gamma = \frac{1}{\gamma} : \frac{1}{\alpha}$.

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I, OE parallel to ID, ED tangent at E and EN normal to IO, then are OI and OE conjugate radii and the parallelgram $OEDI$ is of constant area $O\mathfrak{c} \times O\mathfrak{a}$, hence, $O\mathfrak{c} \times O\mathfrak{a} = OI \times EN$. Let OA denote the normal at O equal $O\mathfrak{a}$.

Describe the circumscribing circle or section of the ordinary shell, then* are OI and OH the velocities of extraordinary and ordinary ray v_e and v_0.

From $O\mathfrak{c} \times O\mathfrak{a} = OI \times EN$, have $OI = v_e = \dfrac{O\mathfrak{c} \times O\mathfrak{a}}{EN}$

From $OH = O\mathfrak{c}$ and $OA = O\mathfrak{a}$, $OH = v_0 = \dfrac{O\mathfrak{c} \times O\mathfrak{a}}{OA}$

that is $v_e : v_0 = \dfrac{1}{EN} : \dfrac{1}{OA}$ or $EN : OA = \dfrac{1}{v_e} : \dfrac{1}{v_0}$

Moreover, EN in the principal section and OA normal to it are respectively the directions of vibration of rays to which they correspond.

That is: For any diameter of the ellipsoid considered as a direction of transmission there are two points of the surface, the normals to which are also normal to that diameter. *These normals are at once the directions of vibration and the reciprocals of the velocities of the rays transmitted in the direction of the diameter.*

DERIVATION OF POSITIVE RAY SURFACE.—Upon $\mathfrak{a}$ and $\mathfrak{c}$, Fig. 226, the directions of vibration of the fastest and slowest rays make $O\mathfrak{a} = \alpha$ $O\mathfrak{c} = \gamma$. $O\mathfrak{c}$ is the axis of rotation and the ellipsoid resulting is the indicatrix.

Section $\mathfrak{ac}$ *of Ray Surface.*—For the direction $O\mathfrak{c}$ the two normals are $O\mathfrak{a}$ and $O\mathfrak{a}$, for the direction $O\mathfrak{c}$ the two normals are $O\mathfrak{a}$ and $O\mathfrak{c}$, for any other direction, OI, the two normals are $O\mathfrak{a}$ and EN, in which EN varies between $O\mathfrak{a}$ and $O\mathfrak{c}$ according to the direction of transmission.

According to the rule then this section of one shell is a circle with constant radius $\dfrac{1}{O\mathfrak{a}} = \dfrac{1}{\alpha}$ and of the other shell is an ellipse with axis in direction $\mathfrak{a} = \dfrac{1}{O\mathfrak{c}} = \dfrac{1}{\gamma}$ and in direction $\mathfrak{c} = \dfrac{1}{O\mathfrak{a}} = \dfrac{1}{\alpha}$ corresponding exactly to Fig. 226.

SECTION $\mathfrak{aa}$.—For every direction of transmission two no alsm exist, $O\mathfrak{c}$ and $O\mathfrak{a}$; that is, this section of the double surface is two concentric circles with radii $\dfrac{1}{O\mathfrak{c}} = \dfrac{1}{\gamma}$ and $\dfrac{1}{O\mathfrak{a}} = \dfrac{1}{\alpha}$.

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Determination of Optical Characters.

The determination of the optical characters of a uniaxial crystals consists essentially in the *determination of the axes of the Indicatrix;* that is, of the principal indices of refraction (indices of the two rays transmitted normal to the optic axis c). The determination may be direct or indirect.

Direct Determination of Principal Indices of Refraction.

(a) Prisms with refracting edge B, Fig. 212, parallel to the optic axis give for minimum deviation, p. 116, a direction of transmission RS normal to the optic axis.

(b) In prisms with refracting edge B, Fig. 212, perpendicular to the optic axis and faces AB and AC equally inclined thereto the optic axis is BD and the direction of transmission RS for minimum deviation is normal to it.

Because the horizontal section aa of the ray surface is two concentric circles, the formula p. 117 holds good for both rays

$$\alpha = n_1 \frac{\sin \tfrac{1}{2}(\delta + x)}{\sin \tfrac{1}{2} x} \qquad \gamma = n_1 \frac{\sin \tfrac{1}{2}(\delta' + x)}{\sin \tfrac{1}{2} x}$$

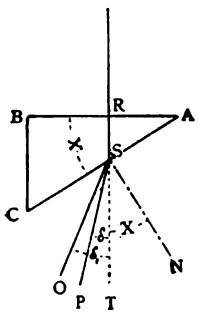

FIG. 228.

(c) In a prism ABC, Fig. 228, with one face AB parallel to the optic axis, rays normally incident* at that face experience no refraction, because in sections normal to the optic axis both shells are circles, but on emergence from the second face the two rays are differently refracted.

Denoting the prism angle by x, the deviation of the faster ray by δ and that of the slower ray by δ' and measuring these only we have:

$$\alpha = n_1 \frac{\sin PSN}{\sin TSN} = n_1 \frac{\sin (x + \delta)}{\sin x}$$

$$\gamma = n_1 \frac{\sin OSN}{\sin TSN} = n_1 \frac{\sin (x + \delta')}{\sin x}.$$

* With this face vertical and any convenient angle between collimator and telescope obtain signal from the fact by turning the crystal, turn the crystal then further one-half this angle until normal to the collimator.

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(*d*) The indices α and γ may be calculated from the indices obtained with other prisms.*

(*e*) In *any* crystal face or section one of the extinction directions, p. 145, is in a plane through the optic axis and the other is at right angles thereto and, therefore, is itself at right angles to the optic axis.

If this direction is made horizontal in a total reflectometer the transmission will be at right angles to the optic axis and the methods and formulæ of pp. 118–123 will be available. There will be two distinct limit lines which may both be in the field at once as in Fig. 229 or may not; they are successively brought into coincidence with vertical hair.

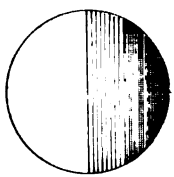

FIG. 229.

The measurements determine the relative values of α and γ. By means of a nicols prism, p. 133, which transmits only light vibrating in a plane through its shorter diagonal, the ordinary and extraordinary rays may be distinguished, the former being transmitted when the shorter diagonal is at right angles to the optic axis, the latter when these are parallel as previously explained.

In positive crystals the ordinary is the faster, that is, corresponds to α.

In negative crystals the ordinary is the slower, that is, corresponds to γ.

Indirect Determination with Plane Polarized Light.

Parallel faced (plane-parallel) sections of known orientation are prepared. Cleavages are used when obtainable, or if the section is to be parallel to a crystal face this face is cemeted to a glass and an opposite artificial face ground on with emery and polished with rouge. When the desired section is not parallel to any known face it is fastened to glass by slowly hardening cement, adjusted at the proper angle and ground, the new face being verified goniometrically with reference to other faces.

Crystals soluble in water are ground in some other liquid, as mono-brom napthalin or benzine, and if fragile are ground only on a glass plate. After grinding the sections are cleaned and transferred to another plate.

A very perfect apparatus in which true planes may be rapidly

* Th. Liebisch, Phys. Kryst., 1891, 384–390.

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ground accurately within 10′ of any desired direction has been described by A. E. Tutton.*

PLANE POLARIZED LIGHT may be produced from common light.

(*a*) By reflection at a particular angle of incidence (tan $i = n$), the vibrations being at right angles to the plane of reflection (plane through incident and reflected ray).

(*b*) By refraction through a series of parallel glass plates, each plate increasing the proportion of polarized light. In this case the vibrations are in the plane of reflection and common light is always present.

(*c*) By double refraction and total reflection of one of the rays. The best known device for securing this effect is the so-called Nicol's prism,† made from a cleavage of calcite with a length about twice its thickness, Fig. 230. The two small rhombic faces at 71° to the edge are ground away and replaced by faces at 68° to the edge. The prism is then cut through by a plane at right angles both to the new terminal faces and to the principal section. The parts are carefully polished and cemented by Canada balsam, the index of refraction of which is 1.54 or about that of the extraordinary ray *bd*, which, therefore, passes through the balsam with but little change in direction; the ordinary ray *bc*, however, with an index of refraction of 1.658, being incident at an angle greater than its critical angle, is totally reflected. The vibration direction of the emerging light is, therefore, parallel to the short diagonal of the face of the nicol, as shown by the arrow.

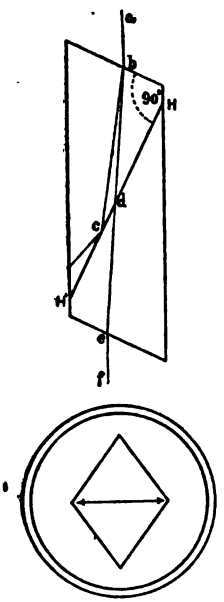

FIG. 230.

(*d*) By double refraction and absorption. Certain substances absorb one ray much more rapidly than the other, hence thicknesses can be

* *Proc. Royal Soc.* 1894. Vol. 55, p. 108.

† Described *Jamesons New Journal*, V. 6 1828. Various modifications of this prism have been made to decrease the cost and increase the field. See *Zeit. f. Kryst.*, XI., 179, 410, for instance.

The Foucault's prism uses, a layer of air instead of Canada balsam and is cut at a different angle requiring a shorter prism but giving a smaller field.

In the Hartnack prism the terminal planes are at right angles to the axis, the prism is shorter and the field reaches 42°. It is much used.

The Bertrand prism is of flint glass with the high index of refraction of 1.658. It is bisected by a plane at 76° 43′ to the base and between the two halves is a thin calcite

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chosen for which one is totally absorbed, the other is partially transmitted as light, the vibrations of which are in one plane. In tourmaline the ordinary ray is the more rapidly absorbed.

INTERFERENCE.—A ray of polarized monochromatic light *AB* Fig. 231, incident at the lower surface of a plane-parallel doubly refracting plate at any angle is broken into two rays *BC* and *BD*, vibrating in planes at right angles to each other and following different paths in the plate. On emergence they follow parallel but not coincident paths and do not produce interference.

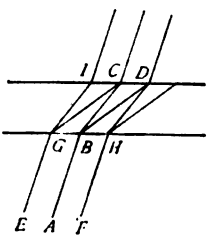

FIG. 231.

But among the other incident rays from the same source and parallel to *AB* there are rays *EG* and *FH*, such that from all points *C* and *D* of the upper surface there will emerge the ordinary component of one ray and the extraordinary of another following the same path. These rays will have travelled over slightly different paths in the plate with different velocities.

If a second polarizer is placed in the path of these rays each ray will be by it resolved into components the vibrations of which are in and at right angles to the plane of vibration of the polarizer and only the former will be transmitted. That is, there will emerge two rays advancing in the same line and with parallel vibrations. If these vibrations are alike in phase the intensity of the resultant ray will be proportionate to the square of the SUM of their amplitudes, but if unlike in phase the intensity will be proportionate to the square of their DIFFERENCE.

POLARISCOPES.—The instruments used for producing and studying the interference phenomena are called POLARISCOPES. In these parallel rays of plane polarized light, or converging bundles of parallel rays, are incident at one surface of the plate at a known angle, traverse the plate undergoing single or double refraction according to its nature; and, if doubly refracting, the rays following the same path are reduced by the analyzer to one plane of vibration producing interference phenomena.

The essentials of a polariscope for parallel light are shown in

cleavage properly oriented. The light enters the prism, and reaching the calcite is doubly refracted; the ordinary ray, with a refractive index about that of the glass, continues its course; the extraordinary with a much lower index is totally reflected. The field is about 45°. *Compte Rendu, Acad. Sci.*, Sept. 29, 1884.

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Fig. 232. The mirror M sends parallel rays through the lower lens L, which concentrates them at the centre of the polarizer P; this point is also the focus of the equivalent upper lens L. On emergence from L the rays are again parallel, undergo refraction in the plate S of the substance and reach the analyzer A, which transmits only those components of the resultant rays the vibrations of which are in its own plane.

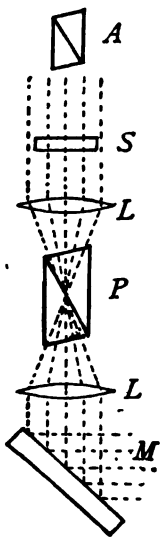

Fig. 232.

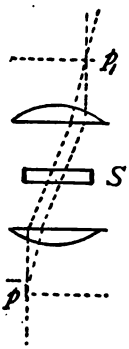

Fig. 233.

Convergent light is obtained by the addition of a lens or system of lenses of short focal length just above the plate S and a corresponding system just below the plate, Fig. 233. Any point p of the focal plane of the lower lens system is illuminated by a cone of rays the base of which is the lens. This cone is made a cylinder of parallel rays by the lens. The rays of each cylinder which traverse the plate are again concentrated by the upper lens system at points p', etc., are sorted by the analyzer and finally exhibit a picture or image the shape brightness and tints of which depend upon the structure of the plate for all the directions traversed by the cylinders of parallel rays.

The polariscope of to-day is usually a polarizing microscope. In the simpler types, such as the Seibert* 11 *A*, the polarizer below the stage can be raised, lowered and turned; the analyzer above the objective can be pushed in and out and convergent light images can be obtained with high power objective by placing a small convergent lens on top of the polarizer, raising the latter till it touches the section and removing the eye-piece. An orifice above the objective is always provided for the insertion of test plates, p. 146, and with increasing complexity there are added special micrometer eye-pieces, Bertrand lens for magnification of convergent light image, sliding motions of the stage and so on.

* For description of this instrument and its manipulation, see L. McI. Luquer, *S. f. M. Quarterly*, 1896, p. 442–445.

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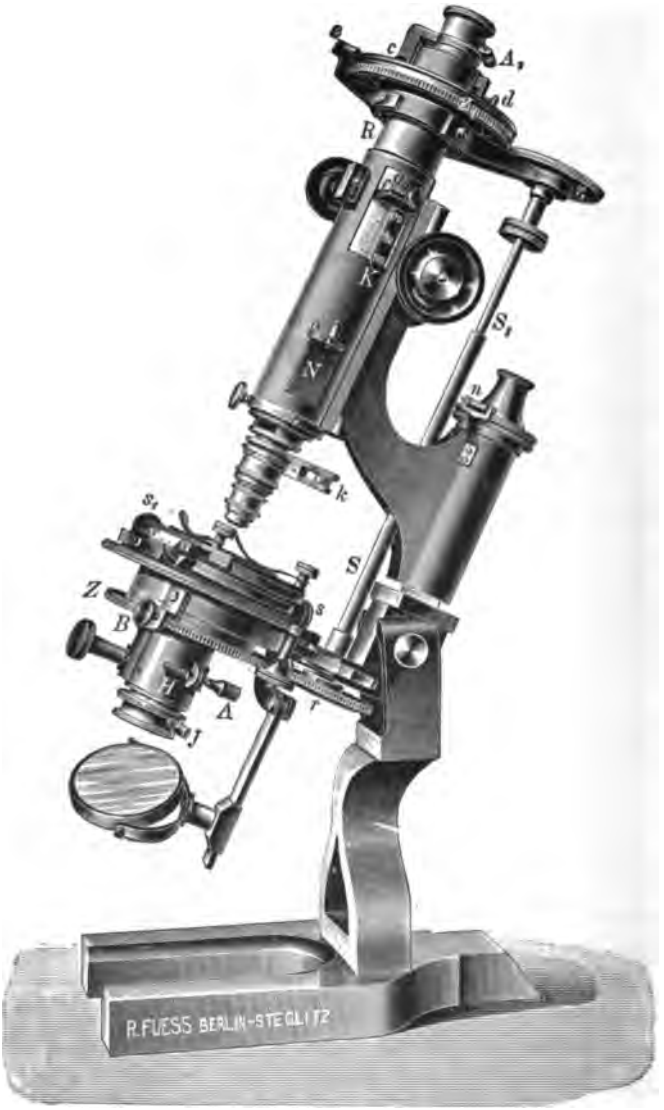

FIG. 234.

The Fuess microscope * model VI., Fig. 234, is at present probably the finest instrument made for this work. The stage reads to minutes and has quick rotation by hand, slow rotation by ratchet and sliding motions in two directions. There is an independent

* *Neues Jahrbuch f. Mineralogie* Beilage, Bd., X., 180, by C. Leiss.

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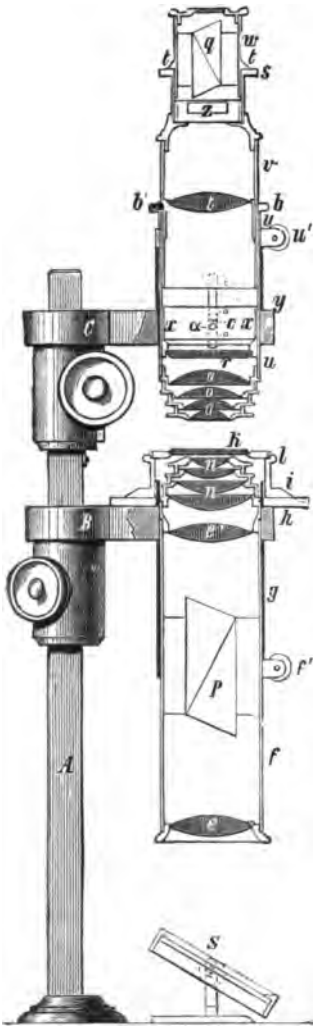

FIG. 235.

FIG. 236.

focussing screw for the interference figure and a special device of cog wheels r Z, r^1 Z^1, by which there may be a simultaneous rotation of polarizer and a special cap analyzer, the object remaining at rest, but the same relative change taking place as if the stage were revolved and the nicols at rest.

Two forms of the Norremberg apparatus as constructed by Fuess are here shown. Fig. 235 shows the so-called Universal

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Apparatus, ee' are collecting lenses on each side of the polarizer; above e' are four plano convex lenses, n, forming the condenser and just over these the stage.

In a separate tube system above are the objective, composed of four similar plano convex lenses o, and at their focal plane the glass plate r, on which a cross and a scale are marked; the image there formed is magnified by t and viewed through the analyzer q.

By removal of n, o, r and t the apparatus yields parallel rays.

Fig. 236 shows a later less expensive type, in which the lower nicol is replaced by a pair of mirrors. The high cost of iceland spar is the principal reason for the change and the results are very satisfactory.

WITH PARALLEL MONOCHROMATIC LIGHT, AND CROSSED NICOLS.

With crossed nicols none of the light from the polarizer can penetrate the analyzer and the field must be dark.

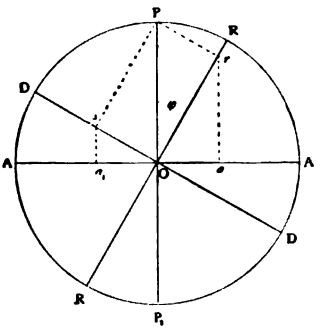

FIG. 237.

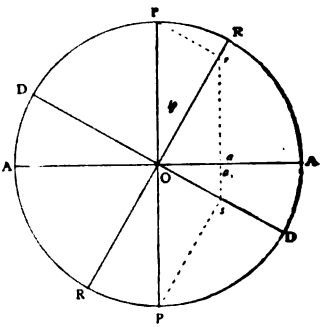

FIG. 238.

In sections normal to the optic axis the field remains dark throughout the entire rotation of the stage, and no interference phenomena are possible, because the light from the polarizer traverses the section in the direction of the optic axis, therefore, without change.

In all other sections there is double refraction and interference. The field is dark at intervals of 90°; that is, whenever the planes of vibration of the rays produced in the section coincide with the planes of vibration of the nicols. For all other positions the field is illuminated by the components of the rays which penetrate the analyzer and this brightening is most intense in the diagonal positions.

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The rays pursuing the same path are by the analyzer brought into one plane of vibration and there interfere, the kind of interference being determined by $\triangle$, the difference in the retardations which the two rays have undergone, the formula being*

$$\triangle = t\left[n_1 - n + \sin^2 i\left(\frac{1}{n} - \frac{1}{n_1}\right)\right]$$

Or for normal incidence,

$$\Delta = t(n_1 - n)$$

In which Δ is the retardation (difference in retardation) in $\mu\mu$ millionths of a millimeter.

t is the thickness of the plate in $\mu\mu$.

i is the angle of incidence.

n_1 is the index of refraction of the slower ray.

n is the index of refraction of the faster ray.

When $\Delta = \lambda, 2\lambda, 3\lambda$, etc., the field is dark during an entire revolution, for Fig. 237, the components of PP on emergence from the plate must be of the same phase that is the simultaneously displacing forces acting upon any ether particle O are Or and Os, which are reduced to the plane of the analyzer are Oa and Oa_1, which are opposite and equal.

Fig. 239.

When $\Delta = \frac{1}{2}\lambda, \frac{3}{2}\lambda, \frac{5}{2}\lambda$, etc., the light will be at its brightest because the components of PP must then on emergence from the plate be of opposite phase, fig. 238, and the simultaneous displacing forces acting on any ether particle O are Or and Os, which reduced by the analyzer to its plane are Oa and Oa_1 in the same direction and equal.

EXPERIMENT.

If a wedge of double refracting crystal, Fig. 239, cut so that its planes of vibration are parallel to the length and breadth, is placed between crossed nicols and illuminated by perpendicularly incident monochromatic light and there revolved.

It will be perfectly dark when in the normal positions and in all others will show a series of dark and light parallel stripes which are most marked in the diagonal position. If the nicols are made parallel the portions formerly light become dark, with light of a different wave-length, the distance between the dark bands is changed.

* Reduced from formula, p. 364, Glazebrook's *Physical Optics.*

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*These relations may be deduced from the formula for intensity of emerging light

$$I = a^2 \sin^2 2\varphi . \sin^2 \left(\frac{\pi \Delta}{\lambda}\right)$$

in which

a = amplitude of incident ray λ = wave-length

Δ = retardation φ = angle between vibration plane of lower nicol and slower ray.

I will be a minimum.

(a) when $\sin^2 2\varphi = 0$ or $2\varphi = 0°$, 180°, 360°, 540°, etc., or $\varphi =$ 0°, 90°, 180°, 270°; that is, four times in a revolution of the plate or whenever the planes of vibration of the plate coincide with those of polarizer or analyzer.

(b) when $\sin^2 \left(\frac{\pi \Delta}{\lambda}\right) = 0$ which will be whenever $\frac{\Delta}{\lambda} = 1, 2, 3,$ etc., that is whenever the phase difference Δ is a multiple of λ, for then $\sin^2 \left(\frac{\pi \Delta}{\lambda}\right)$ becomes $\sin^2 180°$, or a multiple thereof.

This is independent of φ, hence with this condition the plate will remain dark an entire revolution.

I will be a maximum.

When $\sin^2 2\varphi = 1$ or $2\varphi = 90$, 270, etc., and $\varphi = 45°$, 135°, 225°, etc.

When $\frac{\Delta}{\lambda} = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, for then $\sin^2 \left(\frac{\pi \Delta}{\lambda}\right) = \sin^2 90°, \sin^2 270°$, etc. $= 1$. This will be independent of φ and the illumination will exist throughout an entire revolution.

With Parallel White Light and Crossed Nicols.

In sections normal to the Optic Axis the field is dark throughout the rotation, the optic axis being the same for all colors.

In all other sections there is extinction every 90° and greatest brightness in the diagonal positions, but, since Δ may be at the same time approximately an even multiple of $\frac{1}{2}\lambda$ and an odd multiple of $\frac{1}{2}\lambda'$, light of one wave-length may be greatly weakened while that of another wave-length is practically undimmed; that is, there will result a tint due to unequal changes in all the colors.

As Δ increases in value it passes alternately through $\frac{1}{2}$, 1, 3/2, 2, 5/2 times each wave-length as shown in Fig. 240, in which the

*Th. Liebisch, *Grundriss der Phys. Kryst.*, 1896, p. 271–275.

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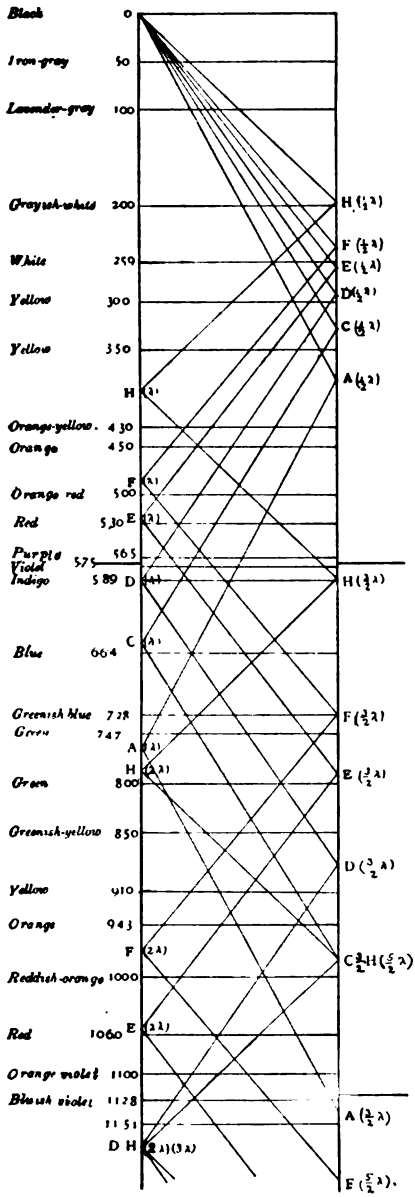

FIG. 240.

zigzag lines show the changes in brightness for six of the colors.* The tint corresponding to any value of Δ may be judged by noting which colors are near maximum and minimum.

FIRST ORDER COLORS.

$\Delta = 0$.—All light is shut out; as Δ increases $\frac{1}{2}\lambda$ of violet is first reached and $\frac{1}{2}\lambda$ of blue and green next.

$\Delta = 100\ \mu, \mu$.—The weakly coloring violet and still fainter blue and green give a total impression of *lavender gray*, which gradually brightens as the other colors show through.

$\Delta = 259\ \mu, \mu$.—The color is *pure white*, after which the violet end begins to diminish in intensity and the red end to increase.

$\Delta = 300\ \mu, \mu$.—Bright yellow is at a maximum and violet nearly extinguished. Green and red are weakened and together produce white, hence the predominating color is *yellow*.

$\Delta = 450\ \mu, \mu$.—The yellow is still high, but the red rays are at or near their maximum and the other rays relatively weak; the color is therefore *orange*.

$\Delta = 530\ \mu\mu$.—Violet and red are about equally near a maximum, green is extinguished and

* The values of λ for these in $\mu\mu$ (millionths of a millimeter) are H_1(violet), 393.3; F_1(blue), 486.0; E(green), 526.9; D_1(yellow), 589.5; C(red), 656.2; A(red), 760.4.

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blue and yellow weak, hence the strongly coloring *red* predominates.

SECOND ORDER COLORS.

$\Delta = 575\ \mu\mu$.—This is $3/2\ \lambda$ for the brightest violet, λ for brightest yellow and red and blue much weakened, hence the total impression is *violet*, often called *sensitive violet* and used in testing because with very slight change in Δ it becomes either red or blue.

$\Delta = 589$ yields *indigo blue*.

$\Delta = 664\ \mu\mu$.—This is $3/2\ \lambda$ for the brightest blue and is λ for orange red and near it for yellow, hence predominating tint is *blue*.

$\Delta = 800\ \mu\mu$.—This is $3/2$ for bright green and near λ for outermost red and $2\ \lambda$ for violet, hence the color is a mixture of green, blue and yellow; that is, *green*.

$\Delta = 900\ \mu\mu$.—This is $3/2\ \lambda$ for yellow and $2\ \lambda$ for blue. Some red and violet emerge with the yellow; that is, the prevailing color is *orange*.

$\Delta = 1060\ \mu\mu$.—This $2\ \lambda$ for green, $3/2\ \lambda$ for some red, $5/2\ \lambda$ for indigo, and as red is the stronger color *red* predominates.

COLORS OF HIGHER ORDERS.

$\Delta = 1130\ \mu\mu$ yields *sensitve violet No. 2*.

With increasing values for Δ the latter becomes an approximately perfect multiple of $1/2\ \lambda$ or λ for an increasing number of wave-lengths and the colors resulting are less pure and brilliant, for example:

$\Delta = 1590\ \mu\mu$.—This is $5/2\ \lambda$ for orange red, $7/2\ \lambda$ for indigo, $3\ \lambda$ for green, $2\ \lambda$ for red, $4\ \lambda$ for violet. The resultant total effect is a *red*.

With the still higher values this is further noticeable and beyond the fourth order the tints resulting are not to be distinguished from white. Hence thick crystals show no polarization colors.

Experiment. The quartz wedge with white light will show colors in the order named, or the Federow mica wedge may be used or assuming the value of $(n_1 - n)$ for special minerals and by measuring t the colors in plates of different thicknesses may be compared.

The colors of corresponding thicknesses of the mica wedge, in which $n_1 - n = .042\ \mu\mu$ are much higher than for quartz with $n_1 - n = .009\ \mu\mu$, one fifth the thickness producing the same retardation in mica.

The thicknesses corresponding to an interference color of red of first order, $\mu\mu = .009$, for several common minerals are in millimeters approximately.

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Calcite	0.003	Quartz	0.060
Muscovite	0.013	Gypsum	0.061
Chrysolite	0.015	Orthoclase	0.079
Barite	0.048	Apatite	0.124

WITH CONVERGENT LIGHT AND CROSSED NICOLS.

The bundles of parallel rays, p. 135, each produce interference phenomena similar to those described, but since for oblique incidence

$$\Delta = t\left[n_1 - n + \sin^2 i\left(\frac{1}{n} - \frac{1}{n_1}\right)\right]$$

the values of Δ corresponding to odd or even multiples of $\frac{1}{2}\lambda$ will depend not only on the value $(n_1 - n)$ and the thickness, but upon the angle of incidence.

In sections normal to the Optic Axis there will be a dark cross, the arms of which intersect in the optic axis (centre of field) and remain parallel to the vibration planes of the nicols during rotation of the stage.

With monochromatic light, if the section is not too thin,* the optic axis will be surrounded by concentric circles alternately dark and light, Fig. 241. If the greatest value of Δ is less than λ no rings will show.

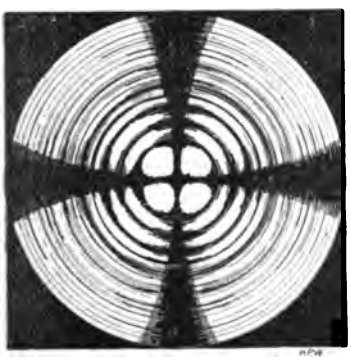

FIG. 241.

The distance apart of the dark rings decreases as the thickness of the section increases and as the distance from the centre increases, for both causes merging sooner or later into a uniform brightness.

With white light the rings become color rings strictly in the order of Newton's colors if the space permits, but often overlapping and finally merging into essentially uniform tints.

* In the accidental orientation of rock sections there is rarely found a perfect basal section and the thickness is usually insufficient to produce rings. The uniaxial figure is nevertheless to be recognized in not too oblique sections by one or both arms of the straight armed cross which remain straight and parallel to the original position on rotation of stage, whereas in biaxial not only do the arms curve into hyperbola, but revolve in opposite directions to the rotation of stage.

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The dark rings correspond to $\Delta = \lambda, 2\lambda, 3\lambda$, etc., and since (p. 128) the indices of the extraordinary ray are alike for all directions, equally inclined to the optic axis, $n_1 - n$, must be constant for any one value of i; that is, these rings must be circles.

The cross results from the planes of vibration of the different bundles being parallel and normal to different principal sections through bundle and optic axis. For any one position of the stage the vibration planes of certain bundles will be in the diagonal positions and those of others will coincide with the planes of the nicols; that is, the light circles will grade from greatest brightness in the diagonal positions to total darkness parallel to the nicols and as the stage is rotated successive rays will come into these positions, maintaining the same effect.

In Sections oblique to the Optic Axis the curves must be symmetrical to a principal section through the plate normal and the optic axis. If the optic axis shows in the field it will change its position with rotation of the stage, but the arms of the dark cross will always remain parallel to the planes of the nicols, Fig. 242, or only one arm may show.

FIG. 242.

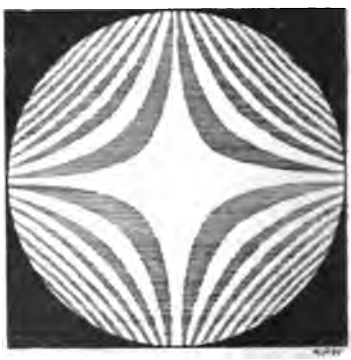

FIG. 243.

In sections parallel to the optic axis the curves are symmetrical to the principal section through the plate normal and optic axis and to a plane at right angles to the optic axis and are conjugate hyperbolæ, Fig. 243.

WITH PARALLEL NICOLS.

The change from crossed to parallel nicols reverses all the phenomena of interference, p. 139. When $\Delta = \lambda, 2\lambda, 3\lambda$, etc., the

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light is at its brightest and when $\Delta = \frac{1}{2}\lambda, \frac{3}{2}\lambda, \frac{5}{2}\lambda$, etc., the light is extinguished. That is with the quartz wedge the thicknesses which were dark bands in monochromatic light with crossed nicols will be light and the light bands dark and with white light the color produced will be complementary to that obtained with crossed nicols.

With convergent light all bright portions of the field are extinguished and all dark portions become bright. With white light the complementary colors result.

If an interference color is passed through a prism the spectrum will show the dark bands in the positions of the extinguished colors.

DETERMINATION OF PLANES OF VIBRATION OR "EXTINCTION."

In any section of a uniaxial crystal the plane of vibration of the extraordinary ray passes through the optic axis and the corresponding extinction direction is the projection of that axis on the section; the plane of vibration of the ordinary ray is at right angles to this.

The positions of darkness or extinction directions are always either parallel or symmetrical to cleavage cracks and crystal outlines.

The polarizing microscope is nearly always used in determination, the reference outline or cleavage being placed parallel to one of the cross hairs, then the analyzer pushed in and the stage turned to the position of maximum darkness.

A color contrast is more easily judged; this is most simply obtained by inserting between the nicols a test plate (quartz yielding sensitive violet or gypsum yielding first order red). The section is then inserted so that it covers part of the field only, and at position of extinction the entire field will be of the color produced by the test plate, but for any other position there will be a difference in tint.

A special eye-piece may be used, for instance, the Bertrand ocular, the four quadrants of which are equally thick basal sections of alternately right and left handed quartz; the lines of contact take the place of the cross hairs. Before the introduction of the crystal section the four quadrants are of the same color.

In the extinction positions the crystal section is colored like the rest of the field, but the slightest divergence from this raises the color of the section in two diagonally opposite quadrants and

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lowers the color in the other two. A special cap nicol must be used instead of ordinary analyzer.

VIBRATION DIRECTIONS OF FASTER AND SLOWER RAYS.

With the extinction (vibration), directions in diagonal position, a test plate of some mineral in which the vibration direction have been distinguished and marked is inserted between the nicols (in a slot always provided) with these directions also diagonal. If the interference color is thereby made higher, the vibration directions of the corresponding rays are parallel; if the color is lowered, the corresponding directions are crossed.

MICA TEST PLATE OR QUARTER UNDULATION MICA PLATE.—A thin sheet of mica on which is marked ε, the vibration direction of the slower ray which in mica is the line joining the optic axes. The thickness chosen is usually that corresponding to a blue gray interference color or say 140$\mu\mu$ which is $\frac{1}{4}\lambda$ for a medium yellow.

GYPSUM TEST PLATE OR GYPSUM RED OF FIRST ORDER.—A thin cleavage of gypsum on which is usually marked α, the vibration direction of the faster ray. The thickness chosen corresponds to an interference color of red of first order or say 560$\mu\mu$, which is essentially λ for a medium yellow.

QUARTZ WEDGE.—A thin wedge of quartz, cut so that one face is exactly parallel to the optic axis. The length of the wedge is parallel to the optic axis, and as quartz is positive this direction is ε, the vibration direction of the slower ray.

THE V-FEDEROW MICA WEDGE.—Fifteen quarter undulation mica plates superposed in equivalent position, but each about 2 mm. shorter than the one beneath it.

The mica plate raises or lowers the value of Δ by one quarter wave-length, the gypsum by about one wave-length and the two wedges by amounts increasing with the distance inserted.

Sections showing only low colors of first order are better tested by the gypsum plate, in which case there is practically considered the effect of the plate on the red of the gypsum.

DETERMINATION OF THE RETARDATION* Δ.

The v-Federow mica wedge inserted with corresponding vibrations directions crossed will for each interposed plate reduce Δ by 140 $\mu\mu$. To render the field dark will require $\frac{\Delta}{140} = n$ plates. Conversely $n.\ 140 = \Delta$, in which n is determined by count.

The quartz wedge similarly used will give an approximate value by counting the number of times the original color reappears, if n times, then is the color a red, blue, green, etc., of $n + 1$ order, for which the value may be looked up in a chart.

The Babinet Compensator consists of two equal quartz wedges

* Difference in Retardation.

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A and B, Fig. 244, so cut that the optic axis c of say A is parallel to the length y and that of B is parallel to the breadth z. Any normally incident ray I will be divided in B into a faster (ordinary) ray vibrating parallel to y and slower (extraordinary) vibrating parallel to z. But reaching A the faster ray becomes the slower, and *vice versa*.

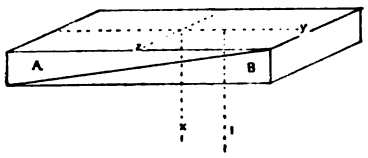

FIG. 244.

For the central position these will exactly balance, and with either monochromatic or white light there will be here a dark band with which a cross hair is made to coincide, and on each side, with monochromatic light, there will be at equal distances from this other parallel dark bands corresponding to $\Delta = \lambda, 2\lambda, 3\lambda$, etc.

Let A be made moveable by a micrometer screw and B be fixed and denote the movement necessary to bring the second dark band into coincidence with the cross-hair by δ, then δ corresponds to λ of the light used, and a movement of $n\delta$ corresponds to a difference of retardation of $n\lambda$.

With the compensator in the zero position and diagonal to the planes of the nicols, introduce a mineral section also in diagona position and determine the motion D necessary to bring back the central band under the cross-hair, this change being due to the mineral, measures the value of Δ in the section, that is, $\Delta = \frac{D}{\delta}$ in wave-lengths, or $\frac{D}{\delta}\lambda$ in millionths of millimeter $\mu\mu$.

If on the scale used, δ is unity, then $D = \Delta$ in wave-lengths.

DETERMINATION OF THE STRENGTH OF THE DOUBLE REFRACTION.—If the thickness of the section is known $(n_1 - n)$ results from $\Delta = t(n_1 - n)$.

DETERMINATION OF THICKNESS OF SECTION.

From formula $\Delta = t(n_1 - n)$, t may be calculated if the value of $n_1 - n$ is known either for the crystal or for fragments of other known minerals ground with the section.

Moderately thick sections (0.5 mm. and upwards) may be measured by fastening on a thin cover glass larger than the section with thin balsam, cleaning away the balsam at the edges by alcohol and focusing successively on dust upon the lower surface of the cover and the upper surface of the glass reference the difference being t.

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Measurements with a micrometer eye-piece, the section being set on edge are sometimes possible.

APPROXIMATE DETERMINATION OF PRINCIPAL INDICES.

The method of the Duc de Chaulnes* as improved by Sorby† depends upon the fact that the focal distance of a microscope is altered when a plane-parallel plate is inserted between the objective and the focus. Sorby focussed upon fine lines ruled on glass and placed some distance below the objective. With polarizer alone the indices corresponding to rays of definite vibration direction were determined either by measuring the displacement due to the unmounted section or successively those due to the glass alone and glass plus section. The thickness of the section and the displacement due to one revolution of the micrometer focussing screw must be known. Then denoting the thickness by t and the displacement by d

$$n = n^1 \frac{t}{t - d}$$

in which if the outer medium is air $n^1 = 1$.

Becke determines the relative indices of two substances in contact in a section by focussing upon the dark boundary line and raising the telescope tube upon which the dark boundary appears to move towards the substance with the higher index of refraction.

TESTS WITH CONVERGENT LIGHT.

DETERMINATION OF CHARACTER OF RAY SURFACE.

MICA TEST PLATE inserted diagonally above a section normal to the optic axis will destroy the black cross and break the rings

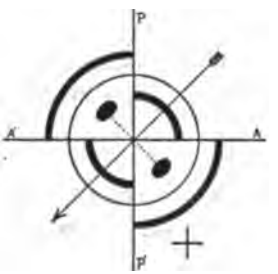

FIG. 245.

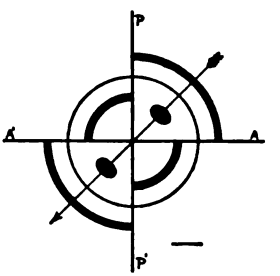

FIG. 246.

into four quadrants, the relative effects in positive and negative crystals being shown in Figs. 245, 246. The corresponding signs

Mem. de l Acad. Paris, 1767–68.

†*Mineral Mag.* I., 193, II. 1.

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+ and — are suggested by the relative positions of the dark flecks and the direction t of the test plate.

After insertion of the test plate t may be said to be at the same time the vibration direction of the slower ray in the mica, of extraordinary rays in the quadrants passed through (first and third) and of the ordinary rays in the other quadrants (second and fourth).

In positive crystals the ordinary ray being the faster there will be an increase of $1/4\ \lambda$ in the first and third quadrants and a decrease of $1/4\ \lambda$ in the second and fourth.

At the centre Δ will now be $1/4\ \lambda$ and no longer dark. In the first and third quadrants the distances between the rings will be decreased about one-fourth by the increase of Δ by $1/4\ \lambda$. In the second and fourth quadrants by the lessening of Δ the spaces between the rings will be increased and near the centre the portion formerly bright with $\Delta = 1/4\ \lambda$ will become $\Delta = 0$; that is, two new dark flecks will be developed as in Fig. 245.

In negative crystals the extraordinary ray being the faster the phenomena are exactly reversed. The centre is light, the rings are narrowed in the second and fourth quadrants and widened in the first and third and in these two dark flecks are developed near the centre as in Fig. 246.

THE GYPSUM RED OF FIRST ORDER may be used in a precisely similar way and is particularly advantageous for very thin or feebly refracting sections in which the rings are almost out of the field. The centre will be red. In positive crystals the first and third quadrants will lower the red to say yellow and in the seeond and fourth near the centre will raise the red to blue. In negative crystals the reverse will take place; that is, the "blue quadrants" correspond in position to the black flecks. This determination must be made in white light.

BY SUPERPOSITION OF A BASAL SECTION OF A MINERAL OF KNOWN SIGN. If the two sections are alike in character this will simply act like a thickening of the plate. If unlike they will partially neutralize each other. This test is little used.

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THE CLEPS-TACHYMETERS.

Description and Methods of Use.

From—"Guide pratique du Géomètre moderne," par A. Salmoiraghi. Milan, 1888.

Translated by C. McK. LEWIS.

1. General.—The cleps instrument is simply the latest form of the Tachymeter invented by Porro, the founder of tachymetry. It consists essentially of a repeating theodolite with a very powerful eccentric telescope, the horizontal and vertical circles of which are, by a special construction, enclosed within a cubical box mounted on top of the sleeve of the alidade. The reading of the angles on the graduations (which are engraved to tenths of decimal degrees [= 5′ 24″]) is accomplished by means of microscopes with fixed threads and by occular estimation.

The horizontal circle is mounted on the axis or pivot of the alidade, and can be oriented at will by means of a magnetic needle attached to the same pivot. All the rotary parts are provided with clamps and tangent-screws, and the whole instrument is mounted on a strong base, with three levelling screws, in the ordinary manner. The tripod itself is of an entirely original construction, designed by Porro, very solid but at the same time very light. The instrument can be moved several centimeters on the tripod top, making it possible to accurately place the center of the instrument (the axis of the alidade) vertically above the station-point, if it should be so desired.

The instrument is described in all its details in the Italian work *Istrumenti e metodi moderni di Geometria applicata per l' ing. A. Salmoiraghi*, of which the first volume, containing the entire theoretical portion as well as a description of surveying instruments in general, has been published.

Plates 1, 2, 3 * represent the three models of cleps as at present constructed in the works of the author at Milan. Further on will be found descriptions of each plate, which will be sufficient to give, from a practical point of view, a complete idea of these instruments.

2. Principles and Data Used in the Construction of this Instrument.—The solution of all the fundamental questions of practical surveying in any of its branches, is dependent upon a preliminary operation which is generally confused with the actual survey,

* Only Plate I. reproduced.

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that is to say, the measuring of the elements necessary for the determination of the positions of the different points on the surface of the earth. This is accomplished, as is known, by the actual measurement of the polar or rectangular coördinates of the points. Of the two systems, the second is the more convenient; but the rectangular coördinates are not adapted to direct measurement. In the great majority of cases it would not even be possible, whereas the measurement of the polar coördinates can always be accomplished and that with relative ease. We can nevertheless, deduce the rectangular coördinates by means of the polar, actually measuring on the ground the angles and linear distances. It may be said that in the "Higher Surveying" distances are very rarely measured (it would be almost impossible to do so), but by geometrical artifices the lengths can always be deduced from some one directly measured base; in Topography proper the same method is not followed; it would be much too long, and besides the actual measuring of small distances is not nearly so difficult. In either case therefore, it will be necessary to provide the surveyor with means for fixing directions and for measuring their angular interval from either a fixed direction or from each other.

3. THE ACUTENESS OF VISION.—Magnification of the telescopes and microscopes in comparison with the diameters of the circles.—Instruments for fixing directions are lines of sight, either of alidades or of telescopes. The great phenomenon of Nature which enables us to utilize these lines of sight, or aims, or visual rays, etc., is that of the rectilinear propagation of light. Still the phenomenon does not exist subjectively without the intervention of the eye. The eye, is therefore, the surveyor's first utensil. Precision in fixing a direction depends exclusively on the aptitude and delicacy of this organ of our senses. The problem of fixing a direction consists in bringing into coincidence the given direction with an instrumental direction which is part of the measuring apparatus. It is, therefore, of extreme importance to know between what limits of precision we can obtain the coincidence which we are to discuss. It is with this property of the eye that we are concerned: that is to say, with the *acuteness of natural vision.* Taking the arithmetical mean of all the most similar results of the experiments to be found recorded in the work of Helmolz, we find: that the value of acuteness for terrestial objects is 90″, for celestial bodies 60″.

Employing a cross-staff for fixing a direction one can arrive at

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a result with a precision of 90″; but if a good telescope enlarging M times is used, a precision of $\frac{90''}{M}$ can be attained. To fix a direction with an accuracy of 10″, a telescope enlarging 9 times would suffice. When employing a telescope, it becomes necessary on account of its enlarging power, to consider the different conditions of clearness in which the viewing occurs. Experiments to this end have shown that in good telescopes when the enlargement is not so great that the diameter of the ocular circle (diameter of the pencil emerging from the eyepiece corresponding to each point of the image) does not become less than 1.2 mm., the distinctness of vision remains the same. But if less, it decreases materially: between 1.2 and 0.75 mm., the distinctness is gradually reduced to nearly ¾ of the normal; that is to say, when the ratio between the diameter of the objective of the telescope, expressed in millimeters, and the magnification M, is less than 1.2, it is necessary to take for the precision of sight $\frac{4}{3}\cdot\frac{90''}{M}$

The same law which we use in judging of the power of a telescope is also applicable in determining that of a microscope. Hence in viewing objects very close to us, as for example, in determining the extremeties of a length, either of an arc or of a straight line (as in reading a circular or rectilinear graduation) the precision to which one can lay claim is limited to the acuteness of vision expressed in seconds, divided by the magnification of the lens, the microscopes, etc. From this it is possible to derive a law for fixing the radius of the graduations and finally for obtaining a result giving the probable degree of precision in the measurement of angles.

An angular reading on a graduation always reduces in the end, to the making of a coincidence between an index mark and one on the graduations, or else in estimating a certain space between two consecutive marks. This however, must be a function of the acuteness of vision. The length of an arc containing f'' on a graduation of radius R is $\frac{fR}{206265}$. If it is desirable to measure to f'' it is evidently necessary that the eye should be able to determine the coincidence to the quantity $\frac{fR}{206265}$ seen at the distance h of distinct vision (about 20 cm.). Now, the quantity $\frac{fR}{206265}$

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subtends at the distance h of distinct vision, an angle which, in number of seconds, is given by the expression $\frac{fR}{h}$. And it is this quantity which must be equal to or greater than 90″, where 90″ is the angle of acuteness of vision. We have, therefore, from these elements the following equation: —

$$\frac{Rf}{h} = 90.$$

Using a lens or a microscope enlarging M times and substituting for h its value of 200 mm. we have:

$$MRf = 18000.$$

It is this equation which gives a law for choosing the dimensions of the circles and the enlarging power of the microscopes, simple (reading glasses) or compound, which will assure a precision in reading, corresponding to a fraction of f''. For example, wishing to employ reading glasses enlarging 12 times and to measure to ten seconds, it would be necessary to engrave the graduations on a limb of 18 cm. radius. This seems enormous, and yet from this same law comes the conclusion that, to determine a direction with a precision of 10″, a telescope enlarging 9 times would suffice! . . . . Our ancestors were indeed right in making their theodolites with large circles and with telescopes whose length did not exceed, or exceeded by but little, the diameter of the circles themselves. They well knew that *before measuring it was necessary to see.* Theodolites are made to-day whose graduated circles have a diameter of only 12 cm., and that with verniers reading to ten seconds and lenses enlarging at the most ten times. It is evident that in this case the precision of 10″ is nothing but an appearance. In reading the verniers there constantly arises a doubt as to which of its divisions is in coincidence; there are always two or three which coincide at the same time. Not that this is really the case, but only that it is impossible to distinguish the differences. It goes without saying that verniers, like all other means of fractionalizing, do not in themselves augment the acuteness of the senses in the appreciation of small quantities. They are excellent means for *bringing out all that it is possible to see.*

It is easy to object, with regard to verniers, that the reading can always be made on the mark intermediate between the two or more which appear equally removed to the right and left from the

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divisions of the graduation; but that is only a begging of the principle; for in reality what is the judge of this *equality* of displacement, if not the eye?

It is very evident that if an endeavor were made to strictly follow the law which has just been enunciated, retaining the verniers and the reading glasses which can hardly enlarge more than 10 or 12 times, it would be necessary to make very cumbersome instruments; but the progress of art has given us the compound microscope with which it is possible to magnify almost indefinitely; it is by the application of this means of reading that the difficulty is overcome, for if on a theodolite similar to the one in the preceding, example, reading to 10″, we were to use compound microscopes enlarging 40 times, it would well suffice to engrave the graduations on the edge of a circle of 45 mm. radius.

The future holds in store the greatest success for the system of reading by microscopes. On all instruments with which it is necessary to have a precision of angular reading assuredly below ⅓ or ¼ of a minute, it is certain that the system of verniers is being abandoned in favor of that of compound microscopes. The latter is simpler and more convenient, as well as easier to use. With microscopes it is also difficult to make any material mistakes which are the most to be feared in practice.

4. Power of Telescopes Considered as Telemetric Instruments.—(1) The measurement of distances by the stadia, like all the analogous measurements termed telemetric, resolves itself into the problem of the solution of a very acute angled triangle, of which we know the value of the small acute angle w and the side opposite it a. On account of the small size of the angle w the triangle can be considered isosceles. The unknown length D of its sides may, therefore, be represented by :—

$$D = \frac{a}{w},$$

that is to say, the unknown length is equal to the quotient obtained by dividing the length of the known side by the acute angle *expressed in radians*. The angle w is constant, the length a is variable, and it varies proportionally to the different distances. The practical making of the measurement reduces itself to the exact determination of the quantity a included between the sides of the angle w; this is accomplished by reading on the rod or stadia the

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positions of the intersections of the visual rays which subtend an angle w. Evidently the precision with which it is possible to determine a depends upon the accuracy with which the angle w can be fixed in space: in other words, on the *ability of the telescope to fix a direction with a certain degree of precision.* Once having determined that the acuteness of natural vision is 90″, and that of telescopes $\frac{90''}{M}$ (M = magnification), all the elements are obtained necessary for an *a priori* appreciation of the precision in the results which can be expected by means of telemetry with the use of stadia. In practice the errors which are liable to be made in the determination of D can be considered as differentials of D with respect to w; then representing by E the error produced in the determination of D by an infinitesimal error in w, either too great or too small,

$$E = dD = \pm \frac{a}{w^2} \cdot dw.$$

But the value of dw, as far as it depends upon the power of the telescope, is simply the error in the fixing of w, that is to say, of two lines of sight, each of which is subject to an error of $\frac{90''}{M}$; and as it is possible that the two errors may be additive, for prudence take:

$$dw = \pm \frac{180''}{M}$$

then in radians:—

$$dw = \pm \frac{180}{M} \cdot \frac{1}{206265}.$$

Hence the error E, in so much as it depends upon the penetrative power of the telescope, can be expressed by the formula

$$E = \pm \frac{a}{w^2} \cdot \frac{180}{M \cdot 206265}$$

but

$$\frac{a}{w} = D;$$

therefore:

$$E = \pm \frac{180}{Mw} \cdot D$$

(w expressed in number of seconds).

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The error is inversely proportional to the magnification of the telescope and to the amplitude of the diastimetrical angle w.

Suppose that

$$w = 0.01 = 2062''.6 \text{ and } M = 20$$

(both values much used in practice), then:

$$E \pm \frac{180}{41252} \cdot D = \pm 0.0043 \cdot D.$$

From this result it must be concluded that even when employing all the precautions necessary to insure the best conditions, there is the liability of an error of 0.43 m. in a hundred; which in the majority of cases in practice would be too large. It does not suffice to simply put some threads in the field of a telescope, in order to rationally apply that which is called *tachymetry*. And yet that is just what is usuually done. The angles are measured to hundredths of a degree; every precaution is taken to center the instrument over the station and then the distances are measured in the manner which has just been indicated. It is necessary to find some way of harmonizing the precision of the different elements of the measurements, in order to arrive at a satisfactory reresult.

The idea might at once be suggested of using the greatest possible magnifying powers and the largest diastimetrical angles, but this brings up another difficulty. The field of a telescope is in inverse ratio to the magnifying power. With an ordinary Ramsden eye-piece an enlargement of 20 times can not be exceeded in order to be able to read on a rod two threads subtending an angle

$$w = 0.01;$$

hence the necessity of constructing special eye-pieces. But even in this case 30 diameters can not be exceeded, which only reduces the error to $\frac{2}{3}$ of that found above; that is to say, to 0.286 m. in a hundred meters. It is, perhaps, even yet too high. An angle w of double the amptitude ($w = 0.02$) might be employed, but it would then be necessary to decrease the magnifying power in order to have a field of view sufficiently extended to be able to read the two threads on the rod; one would have to descend to almost 16 diameters, even when using special eye-pieces; that which would be gained on the one side would be lost on the other. In the cleps instrument entirely special arrangements have been resorted to, namely: multiplication of the read-

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ing threads, high magnifying powers, multiplication of the eye-pieces, and finally an arrangement of a movable eye-piece in front of the micrometer.

5. MICROMETER WITH SEVERAL THREADS.—The first of these arrangements is applied to the cleps intermediate and small models, and to the tachymeters with verniers. Instead of two threads four are inserted: (see fig. 1) a, a', b, b'. Each group of threads, $a\,b$, $a'\,b'$, comprises an angle w of 2062″, equal to 0.01 radians; the two $a'\,b$ subtend an angle w of 0.0040. The magnifying power is about 28 diameters. Each observation is made by reading all four threads $aa'\,bb'$ (each instrument is accompanied by special instructions); two subtractions and one addition are made and the generating number of the distance is obtained. This particular arrangement has two advantages: 1°. By comparing the two differences a check is obtained on the quality of the readings. 2°. It makes each observation depend upon the arithmetical mean of two, so that it is possible to introduce in the denominator of the formula giving the value of E, the term $\sqrt{2}$. Making this change and substituting the known values,

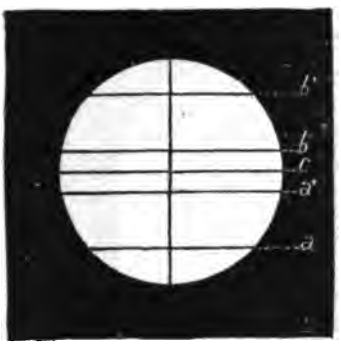

Fig. 1.

$$E = \pm \frac{180}{28 \times 2062.6 \times \sqrt{2}} D = \pm 0.0022.\, D.$$

6. MICROMETER WITH SEVERAL THREADS AND SEVERAL EYE-PIECES (ARGO EYE-PIECE).—Porro surmounted the difficulty of enlarging the field without diminishing the magnifying power by applying to the telescope several eye-pieces; it is proposed to place at the disposal of the engineer three diastimetrical angles so arranged as to enable him to measure in the ratios of 1 : 50 ($w = 0.02 = 4125''$), 1 : 100 ($w = 0.01 = 2062''$) and of 1 : 250 ($w = 0.004 = 825''$). These form three sets of threads which are observed by three small eye-pieces enlarging equally to about 70 diameters. The objective has a clear aperture of 50 mm. This is the telescope applied to the Large model cleps. Figure 2 shows this arrangement enlarged about 10 times. As one can see, there are 15 horizontal

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threads and one vertical. In the figure they are all numbered successively.

Numbers 1, 2, 14, 15, compose the first group *A;* which corresponds to a ratio of $\frac{1}{50}$; 3, 4, 5, 6, 10, 11, 12, 13, the second with a ratio of $\frac{1}{100}$; while 7 and 9 form the third group *C* with a ratio of $\frac{1}{250}$.

To prevent confusion a metal plate is attached to the front of the eye-piece which only allows the threads of one group to be seen at a time. There are only three eye-pieces. The part to which they are attached is capable of being displaced in a groove, when desired by the operator, in such a way that while in the normal position the most separated eye-pieces are in position for viewing group *A*, and the central one, if it be open, group *C;* when in their displaced or excentric position the system of threads *B*, can be seen by two of them. The operation in all its details is easily grasped when one has an instrument at hand. Fig. *F* of plate *I* represents full size the head of the eye-piece on the telescope of a Large model cleps. The plate *p* pushed to the right or left exposes through the holes *A*, *A'* the eye-pieces which make it possible to see group *A;* through *B*, *B'* those for group *B*, and through *C* the one for group *C*. In order to see group *B* it is necessary to gently push the whole piece *O* downwards.

Fig. 2.

The generating number of the distance for group *A*, is determined by taking the arithmetical mean of two numbers; for group *B*, by the mean of four; while for group *C*, which is very rarely used, the determination is a simple one.

If we imagine that the letter applied to each thread in the

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Fig E

Détail de l'oculaire Argo

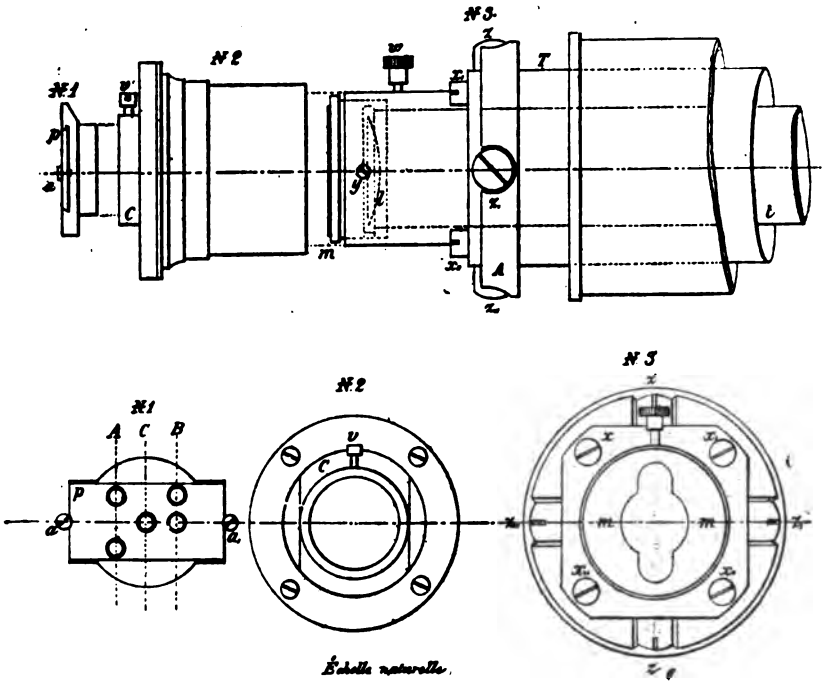

Fig. F

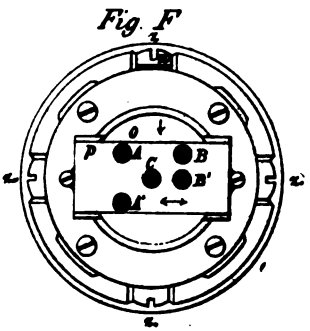

figure represents the corresponding reading on the rod, the generating number D which, with the telescope horizontal, is the actual distance of the rod from the center of the instrument, is obtained by means of the following relations :

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For group *A*

$$D = (a - b) + (a' - b')$$
$$H = (a + b + a' + b')\,0.01.$$

H is the value of the height above the ground of the point of the rod which would be cut by the central thread *c N* 8.

For group *B*

$$D = (a - b) + (a' - b') + (a'' - b'') + (a''' - b''')$$

$$H = (a + a' + a'' + a''' + b + b' + b'' + b''')\frac{0.01}{2} = (a + b''')0.02$$

For group *C*

$$D = 10(a - b)$$
$$H = 0.04\,c.$$

We have as a check in every case, that the values of the binomials in the parentheses should be very nearly equal.

It is to be understood that these equations are applicable only when using Porro's rods with 4 cm. units.

Example: Let us assume the following readings to have been made:

Thread	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Reading	47.02	43.95	39.36	38.13	37.52	36.32	33.20	30.14	27.07	24.06	22.83	22.21	21.00	16.42	13.36

We are here supposing that all of the readings have been made in the same position of the rod in order to present a complete discussion of their treatment and obtain the number called the generator of the distance. But in practice this would never occur, because it would be necessary to displace the shutter and the piece carrying the eye-pieces. In practice, as we have already said, the readings are made with only one group at a time, according to circumstances.

Group *A*, threads 1, 2, 14, 15

47.02	16.42	Difference	30.60
43.95	13.36	Difference	30.59
		Generating number sought	61.19

$$H = (47.02 + 43.95 + 16.42 + 13.36) \times 0.01 = 1.2075$$

Group *B*, threads 3, 4, 5, 6, 10, 11, 12, 13

39.36	24.06	Difference	15.30
38.13	22.83	"	15.30
37.52	22.21	"	15.31
36.32	21.00	"	15.32
		Generating number sought	61.23

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$$H = \frac{\Sigma \text{ readings}}{200} = 1.2071 = (21.00 + 39.36)\ 2 \times 0.01 = 1.2072$$

Group C, threads 7, 8, 9

33.20 27.07 Difference $\times$ 10 = 61.30

30.14

and $H = (33.20 + 27.07)\ 2 \times 0.01 = 1.205$

$H = 4 \times 30.14 \times 0.01 = 1.2056.$

Of the three values of the generating number that derived from group A is supposed to be the most exact, as will be seen more particularly elsewhere.

It is very interesting to investigate the degree of accuracy of the above three values. It must, first of all, be observed that the objective of the telescope being 50 mm. clear aperture and the magnifying power 70 diameters, the coefficient of acuteness can no longer be taken as 90″, but rather 120″; and further that each of the binomials which occur in each group is a term of an arithmetical mean, and hence for group A it is necessary to carry a $\sqrt{2}$ to the denominanator; and for group B, $\sqrt{4}$. With this given, the solution of the general formula for the three cases leads to the following results:

For group A,

$$E = \pm \frac{240}{Mw\sqrt{2}} D = \pm 0.00058\, D = \frac{1}{1724} D;$$

for group B,

$$E = \pm \frac{240}{Mw\sqrt{4}} D = \pm 0.00082\, D = \frac{1}{1220} D;$$

for group C,

$$E = \pm \frac{240}{Mw} D = \pm 0.0041\, D = \frac{1}{245} D.$$

Nothing better could be wished for; as far as the telescope is concerned measurements can be made with the stadia to $\frac{1}{1700}$. Naturally one must not attempt to measure any great distances. It is necessary to keep within the conditions wherein most profit can be obtained from the acuteness of the natural vision. Experience has shown after many repetitions that the above results are perfectly feasible whenever the rod is held absolutely fixed in good atmospheric conditions, up to distances of 150 m.; above this distance the error rapidly increases, so that at 200 m. even with the rod

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held fast, all the above values of E should be considered as doubled. Nevertheless, to measure with a normal probable error of $\frac{1}{500}$ between the distances of 150 and 250 m. is excellent work. It must also be considered that a rod of 4 m. will be too short for group A even at 200 m.; for group B at 400. But the practitioner well knows that it is poor economy to take long sights. The operator who possesses a large model cleps has at his disposition the means for rapidly making exact measurements up to 150 m.; he can use it for measuring the sides of the principle traverses, by placing the stations 300 m. apart, as will be described further on; he can use it as well for the most important determinations of positions; further, he is able to make measurements less exact but still excellent, for the points called detail, up to 400 m.; and beyond that even by employing group C of the micrometer.

7. MOVABLE EYE-PIECE.—A result theoretically equivalent to that furnished by the Argo eye-piece of Porro might have been obtained by carrying a single eye-piece successively before the threads with which it is desired to make the readings. It has been shown that threads subtending a diastimetrical angle of 0.01 can not be used without reducing the magnifying power to almost 15 and certainly to less than 18 diameters; and that as a consequence there is lost in magnification what is gained in amplitude of angle; but it is evident that if we mount the eye-piece on a plate movable at the wish of the operator, in a plane perpendicular to the principle axis of the telescope, as is commonly done for the telescopes of transit instruments, any magnification desired might be used. And that is what has been done. A telescope with a maximum aperture of 45 mm. is used* (in the ordinary construction of tachymeters it would be almost impossible to exceed this opening without making the instrument too clumsey) to which an eye-piece enlarging between 45 and 50 diameters is applied. This eye-piece is movably mounted, as has just been explained, the operator transporting it successively before the threads which he may wish to read. The arrangement is good and the results should be excellent, still, although made use of in other instruments, the makers do not hesitate to say frankly that they have but little confidence in it. In practice it presents a very serious inconvenience; that is to say,

* Observe that it is necessary to distinguish between *clear aperture* and the *diameter of the objective*. Telescopes with large objectives are frequently seen, having, however, diaphraghms in the interior of the tube which sensibly reduce the clear aperture.

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one is never sure of making actually corresponding readings. When the hand is placed on the pointed telescope the latter is liable to be displaced, no matter by how little, and all guarantee of the readings corresponding is lost. The only way of testing its immobility is to repeat the measurement; that is to say, to return to the same conditions. But whilst this form will not admit of verification of the readings, in an instrument with a muliple eye-piece all the readings are made with the hands behind the back. Once sighted, the instrument is not touched again. It may be seen whether the rod has been displaced in the hands of the carrier. Notwithstanding the double number of threads, it is possible to read group *A* in a cleps, much quicker than the two single ones in a fiftieth micrometer provided with a moving eye-piece. Further, the double reading is not wasted; it furnishes a check and a higher degree of precision; it is well worth the trouble of making.

It is easy to criticise the multiplicity of threads which Porro has always employed in order to get the most profitable result from a stadia telescope. But, for that matter, it is not necessary to read them all. Any one of the binomials will give as it stands the distance; it is only necessary to double it in the case of group *A*, or to multiply it by 4 in that of *B*. The greater never excludes the less. But there are many occasions where it would be a satisfaction to have the power of augmenting, with such slight trouble, the accuracy of a measurement.

8. Circles of the Cleps—Details of Construction—Precision of the Readings. It has already been mentioned that the circles of the cleps are enclosed in a box mounted on top of the sleeve of the alidade. A disposition more convenient or practical could not well be imagined. The circles are completely protected not only from the injuries due to atmospheric agencies, but also from all those inevitable in handling. If the instrument were the only thing to be considered, work might be done in any kind of weather. Neither wind, dust nor water would have any effect on it. In addition the instrument is so strongly and compactly constructed that unless accidentally injured it will remain in good condition for service for a long number of years. The first three of these instruments constructed by Porro in 1864, are in the possession of an engineer of Milan, Mr. Carlo Villani, and are still in as serviceable a condition as on their first day, although their owner has been engaged exclusively for the last 23 years in large topograph-

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ical surveys. Even after accidental falls the delicate parts are not destroyed. Repairs are easily made and are within the power of any mechanic. All this has been rendered possible by a considerable reduction in the dimensions of the circles. The graduations on the circles of the large model cleps are engraved on a periphery 58 mm. in diameter, and yet the centesimal degree is there divided into ten parts (4000 divisions) [each division = 5′ 24″]. Those of the intermediate model cleps on a periphery 40 mm. in diameter; the degree still being divided into ten parts (4000 divisions); and finally in the small model cleps the divisions are engraved on a periphery 32 mm. in diameter, the degree being divided into five parts (2000 divisions). All the degrees are numbered regularly from 0 to 399.

The graduations are read by the aid of compound microscopes with fixed threads, by estimating with the eye the tenths and hundredths of the position of the collimation thread between two consecutive marks of the graduation. We have already determined the relation which must exist between the magnifying power M of the reading microscope in diameters and the radius R of the graduations in millimeters, in order that an angular fraction of f'' may be materially visible. This relation was:

$$MRf = 18000.$$

Or since $1'' = 0.^{gr}00032$, the corresponding expression for decimal graduations, assuming for a unit of f a thousandth of a degree would be:

$$MRf = 5600.$$

For the three sizes of circles applied to the cleps, it was proposed to obtain the following degrees of visibility:

Large model cleps, $0.^{gr}005 = 16.''2$; $f = 5$ thousandths of a degree.

Intermediate model cleps, $0.^{gr}010 = 32.''4$; $f = 10$ thousandths of a degree.

Small model cleps, $0.^{gr}020 = 64.''8$; $f = 20$ thousandths of a degree.

Hence reading microscopes enlarging respectively 38, 28 and 17 times were applied.

In consideration of the advantages resulting from a multiplicity of readings, instead of a single collimation thread in the field of the microscope, there has been inserted 3 or 5 in the large model cleps, and three for the others.

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The three figures, 3, 4 and 5 represent the fields of the microscopes of the large, intermediate and small model cleps, in very nearly their apparent size.

At this point it remains to be shown: 1. How, on such small peripheries exact angular graduations can be obtained. 2. That simple estimation by the eye is sufficient for the making of determinations to the fractions indicated.

The graduations on the circles of the cleps are made by the mechanical copying of a standard graduation engraved on a circle 1 m. in diameter. The machine and the graduation were made by Porro. If it be supposed that the working of the machine is not perfect for a graduation of small diameter, neither would it be so for one of large diameter. As to this the facts will settle all doubts and prove that the graduations are exact.

Fig. 3.

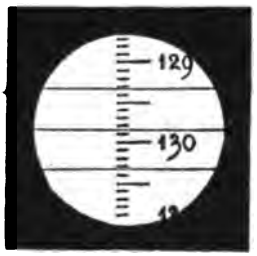

Fig. 4.

Fig. 5.

The circles of the cleps are discs of a special white bronze, extremely hard, which is used in the manufacture of mirrors for telescopes.

On the limb a spherical zone is prepared and optically polished; on this zone the graduations are made with a diamond graver. The hardness of the metal of the circle, as well as that of the graver, renders possible a fine graduation, very sharp and very deep. It is quite possible that owing to the magnification of the microscopes traces of the polishing will sometimes be seen; but that is not a serious inconvenience. The reason for making the limb a spherical zone is most simple.

Once the circles are enclosed in the instrument it is no longer possible to see them without conducting light artificially to the part where the microscope is to be read. This is accomplished by means of prismatic reflectors applied to the exterior of the sides

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of the circle box. The light of the sky is thrown, always at the same inclination, on the polished surface of the limb, which reflects it exactly in the direction of the axis of the reading microscope.* In the case of the small model cleps, both graduations are seen simultaneously in the field of one microscope (see fig. 5).

As to the probable accuracy of the angular measurements, from experiments made by Mr. I'ing. F. Borletti, Professor in the Ecole Polytechnique of Milan, published in the Italian journal *Il Politecnico*, July, 1886, it unexceptionally results, that with a large model cleps, reading but one collimation thread of the microscopes, angles are obtained with a mean error of $0^{gr}.0038 = 12''.3$. Taking the mean of six readings with a single thread made by repitition, we reach $9''.6$; and by reading each time ten threads, to $5''.8$. For the intermediate and small model cleps, the respective values obtained when using a single thread were, $-0^{gr}.0054 = 17''.5$; $0^{gr}.0076 = 24''.6$.

9. Effect of Errors of Eccentricity of the Graduations.—But it might be said that if this proves the accuracy of the graduations and the excellency, generally unknown, of the eye aided by microscopes as a means of fractionalizing, one might still be unpersuaded as to the advisability of employing such small circles on which the unavoidable errors of excentricity of the graduation might become of great importance; the more so as in the intermediate and small model cleps only one microscope is used in reading the angles. Indeed, the unavoidable errors or faults of concentricity between the graduations and the two axes of horizontal and vertical rotation deserve to be considered separately. In the large model cleps there are two reading microscopes for each circle; and inasmuch as they are very nearly in a position to read at the extremities of the same diameter (it is not necessary that they should be exactly in such position) the error of eccentricity is eliminated by taking the arithmetical mean of the readings. This is well known. Provided that the absolute value of the error does not reach the units of degrees, the errors in the two positions nearly diametrical (it is not necessray that the positions of the microscopes be exactly diametrical; a difference of several units of degrees even would only involve errors of a second order in comparison with those of the eccentricity and practically may always be neglected) will always be equal and of opposite

* See in the discription of the plates.

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signs. For the intermediate and small model cleps, the errors of eccentricity are eliminated for horizontal angles by the method of double sights, telescope to the right and telescope to the left, which also serves, as is known, not only to eliminate errors of eccentricity of the graduation, but also those of the adjustment of the line of collimation, the eccentricity of the telescope, etc., etc. For vertical angles it is easy to show that the effect of eccentricity on the determination of differences of level, provided that one does not exceed a limit of ten degrees above or below the horizon (which would even then give the large slope of 1.57%) does not exceed the error proper to the simple observation. For observations more inclined than 10gr, which correspond to points of detail, the corresponding errors can generally be tolerated.

Effect of Eccentricity of Telescope.—It is almost a matter of necessity in the cleps to attach the telescope at some other point than the intersection of the two axes of horizontal and vertical rotation, because, for example, to make room for the telescope of the large model cleps which is almost half a meter long, it would be necessary to elevate the supports of the horizontal axis to a point which would endanger the stability of the instrument; or wishing to avoid this inconvenience, to sacrifice the advantage of reversibility of the telescope. Besides, it is owing to this eccentricity that it is possible to see without the least movement of the body, all the eye-pieces of the reading microscopes of the graduations, and that in the small model cleps the observer can dictate the two angles, horizontal and vertical, to an assistant without even moving the eye. Finally the eccentricity of the telescope renders possible the taking of observations at no matter what inclination without the slightest difficulty; with an eye-piece prism a sight may be obtained, if desirable, at the zenith or nadir. But for many people the eccentricity of the telescope constitutes a great inconvenience. They do not know how to proceed in the divers practical problems which arise; and on that account they voluntarily renounce all the recognized advantages of the new construction, for the older tachymeters with verniers. The error due to this position of the telescope can be considered as occasioned by a lateral displacement of constant value, in the position of the points sighted at, this value being equal to the absolute measurement of the eccentricity itself. This displacement in a large model cleps is equal to 75 mm., for the intermediate 60 mm., and for the small

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model 52 mm. Many authors in discussing this error assert that the effects of eccentricity are negligible for long sights; while for short ones they advise the systematic use of two observations, telescope to the right and telescope to the left, while, according to them, for long sight this precaution may be omitted. All of this is perfectly false. If the error of eccentricity is negligible for long sights it is *just as much so* for short ones. Many other reasons counsel us to operate in precisely the opposite manner. It is always necessary to use the system of double observation for long sights, while for the short ones the same need does not exist. The error due to the eccentricity is constant; only this constant error is translated into an appreciable angular quantity if it be measured near at hand, an inappreciable one if at a distance. The short sight simply renders it appreciable, that is all. It is certain that it would be very satisfactory if the positions of all the points of a survey were exact in absolute measure within a radius of 75 mm.; how much the more is that sufficient when the final object is the making of a map to a scale of even 1:500.

The doubt might arise as to whether, by geometrical transmission in the orientation of station from station, the effect of this error might not be multiplied. But again in this case there is nothing to fear. When the back-sight is made with a difference of 200^{gr} the circle is exactly oriented as in the preceding station. The error of eccentricity committed at the station just left in sighting at the new one, is exactly compensated by that involved in sighting from the new station to the old. The reciprocity is perfect. The orientation of the circle, therefore, takes place perfectly even in instruments with eccentric telescopes. All of the preceding is applicable to the traverses made from place to place. For the important sights for *the bases of the traverses*, one should always make a double observation—*telescope to the right and telescope to the left;* and that as well for instruments with concentric telescopes as for those with eccentric ones. It goes without saying that it is the vertical of the axis of the alidade which must always be placed over the center of the station.

There are also certain operators who find themselves embarrassed by the eccentricity of the telescope, in laying out work—in other terms, in protracting angles on the ground, prolonging alignments, etc. In these cases operate precisely as if a concentric telescope were in use; only, it is to be noted that even with in-

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struments having concentric telescopes, it is necessary to always proceed by means of double observations, circle to the right, circle to the left; for a small defect in the perpendicularity of the horizontal axis and the line of collimation would have a more serious effect than that produced by the simple eccentricity of the telescope. By a double observation two points of the trace are fixed on a rod perpendicular to the direction—the point half-way between the two is the point desired; and that either in the laying out of angles or in the prolonging of lines, for in the end prolonging a line is simply the problem of laying out an angle of 200^{gr}.

References of Plate No. I. Tachymeter Cleps, Large Model.

The telescope is of 50 mill. aperture, is *anallatique* and is furnished with a triple eye-piece enlarging 70 diameters, or with two interchangeable orthoscopic eye-pieces enlarging 30 and 50 times. (Detailed description in paragraph 6).

D_1 D_{11}.—Rings by which the telescope is fixed to the extremity of a strong piece of bronze *T*, made fast to the arbor or material axis of rotation.

In figs. C and D are shown the details of the connection of the telescope to the piece *T*. The screws α, β, β, serve to correct any error in the perpendicularity between the line of collimation and that of the rotation of the telescope. The telescope is centered in itself; that is to say, its line of collimation coincides with the axis of the rings D_1 D_{11}.

S. Box-shaped piece, traversed by the material axis *a* of rotation of the telescope. The axis is hollow to permit of illuminating the field of the telescope during observations at night, if so desired.

R. Sleeve of the alidade, which is fitted on the principal axis of the instrument and to which is fastened the box *S*. The pieces *R*, *S*, *T* and the telescope, taken together, constitute the alidade.

C_1. Vertical circle, formed from a disc of white bronze (the metal of which telescope mirrors are made) adjusted and fastened to the arbor *a*. The graduations are engraved on the peripherical limb, in degrees and tenths of a degree (4,000 divisions). Each degree is numbered from 0 to 399.

C. Horizontal circle; same construction as C_1, this one being adjusted to the top of the principle axis *A*.

A. Principle pivot or axis—a double cone, in which is fixed the magnetic needle.

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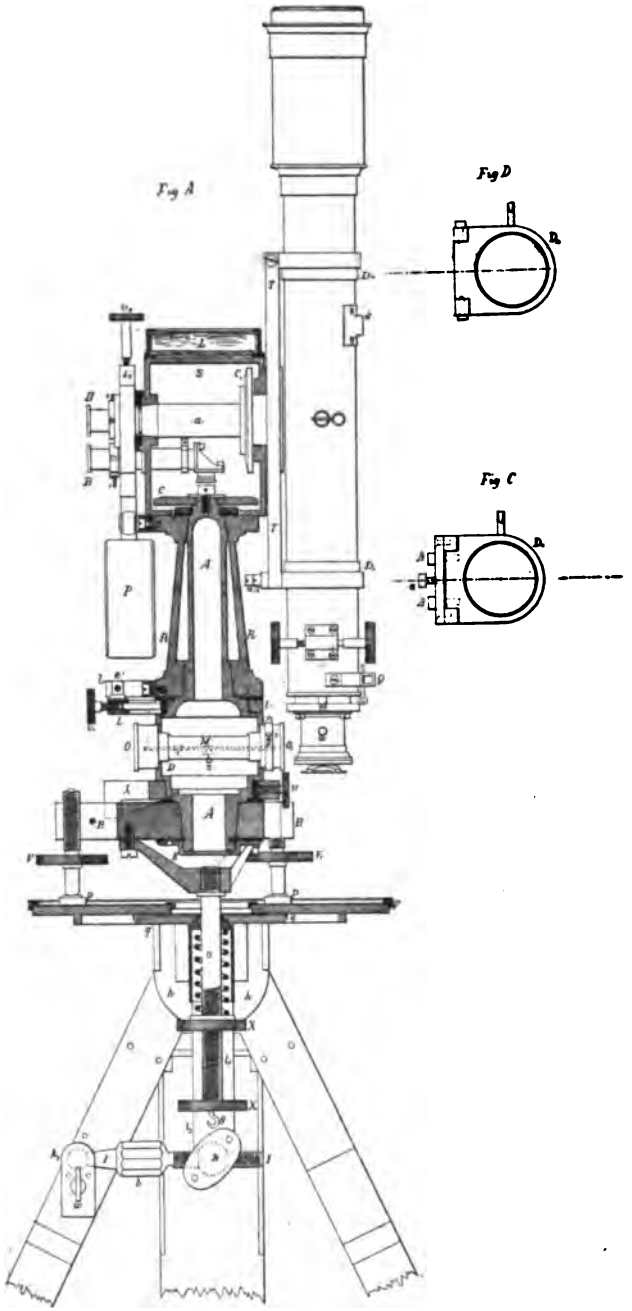

Schultz f.

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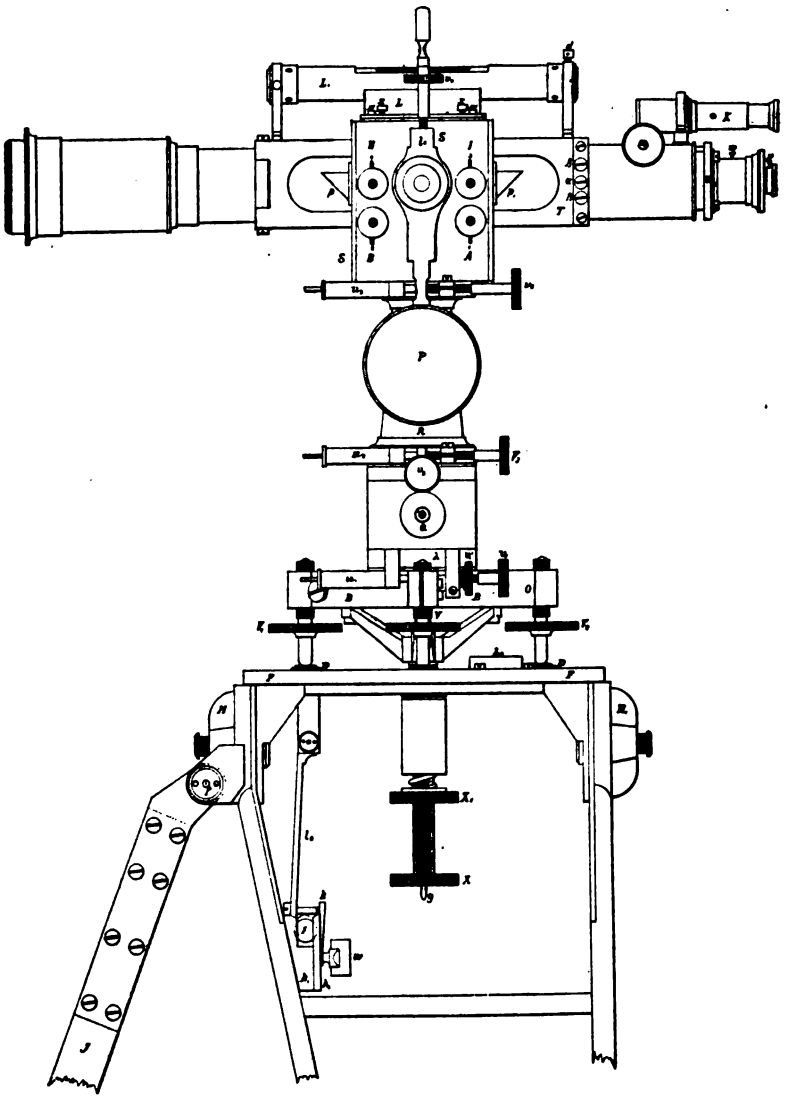
Fig B



M. Magnetic needle, consisting of a tubular shield of copper, in which is placed the needle, pivoted on a point in the ordinary manner.

O, O_1. Covers of the shield or box containing the needle. Of

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these two covers O carries a transparent scale and O_1 a lens which has its focus on the above scale. The needle is slightly bent upwards. The oscillations of the point of the needle are seen enlarged by the lens and in this way the position of equilibrium is fixed on the middle division of the graduation on O. The horizontal circle C, which is above will be oriented in such a way that when the needle of the compass is at rest on the center of the scale on O and when the reading microscopes of the graduation are on the angle zero (0^{gr}, 200^{gr}), the telescope of the alidade will be very nearly in the plane of the magnetic meridian of the station. n, i, ring serving to lift the needle from its pivot.

The instrument being designed for use in all parts of the globe, it has been so arranged as to permit of the Engineer himself correcting for the effect produced on the inclination of the needle by the variation of the magnetic force in the different latitudes. The head O of the shield can be unscrewed, permitting the whole apparatus to be extracted from the other side; the point π can be dismounted, the needle taken from the tube and its inclination examined.

In the box of the instrument is a small pointed support on which the needle can be placed and brought to an exact equilibrium by moving the small counter-weight q; everything being then replaced in its proper position. Naturally, if the needle is working well enough, even if a little inclined, this operation is not performed.

B. Base of the instrument, provided with three levelling screws V, V_1, V_2.

λ. Clamping and slow-motion lever of the principle axis A, used in the orientation of the instrument. The clamping is done by tightening the clamping screw v; the slow motion is obtained by means of the screw v_1 and the spring u_1. The nut v_1' which is tightened after having oriented, serves to maintain the orientation and to prevent one in distraction from laying the hand on this slow motion rather than on that of the alidade. *The safety nut* v_1' once closed, the screw, v_1 will oppose a great opposition to any movement.

l_1. Clamping and slow-motion lever of the alidade. The clamping is done with $v_{1'}$ the slow motion is given by the screw v_3.

l_2. Clamping and slow motion lever of the telescope. The clamping is done with v_4, the slow motion is given by the screw v_5.

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δ. Head of the pinion by means of which the anallatic lens can be moved; allowing of the correction, when needful, of the gauge of the telescope.

It is best not to perform this operation unless well assured by a comparison with some very exact measure (a distance of 50 to 60 m. is sufficient, if measured with every precaution) that it is absolutely necessary. The instruments before leaving the workshops are perfectly gauged, and it is but very recently that the makers have been forced by new customers to furnish this arrangement. However, in certain cases it might render valuable service, but they recommend employing it, with the greatest of care. The key-head of the pinion will be found in the instrument box; the movement should be made little by little. Having the telescope in its normal position (to the right), turning the key in the direction of the hands of a watch will diminish the distances given by the instrument; in the opposite direction will increase them. The rod should be fixed vertically, in order to make this trial, using the smallest graduations and the micrometer group having the largest diastimetrical angle. Finally make a number of readings and judge by the mean. As has already been stated, it is not necessary to take a great distance for this purpose.

P. Weight, partially counter-balancing that of telescope.

1, 2, 3, 4 (fig. B). Prismatic pins attached to the eye-piece end of the microscopes *A*. *B*., I. II., they are the extremities of screws by means of which, when turned with a key, the collimator micrometer of each microscope can be moved by a small amount. In this way the pair of microscopes can easily be made to read at the extremities of a diameter, and the correction to zero for the vertical circle be made very small. Neither of these corrections are at all necessary. It is not of the least importance that the readings of the microscope should correspond to exactly 200^{gr}; it is not even possible, owing to inevitable residual errors in the eccentricity. The object for which the two microscopes are used is perfectly fulfilled, from a practical point of view, if the two readings differ from one another by even entire degrees. As for the correction to zero on the vertical circle, it is made numerically, as was shown in paragraph 29. In the end the screws 1, 2, 3, 4 are more for the convenience of the maker, than for use as actual adjusting screws. There is no need for touching them.

L_1. Striding level, to be placed on the collars of the telescope in

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making the line of collimation horizontal; it serves also to level the instrument when an exceptional precision is desired. Ordinarily the round level L is sufficient. The collars of the telescope are turned to exactly the same diameter. The axis of the telescope is centered on the axis of the collars.

K. Removable Galilean telescope which can sometimes be usefully employed.

xx_1. Screws fastening the spherical level to the circle box, which also serve to adjust it. There are four pairs of them. The x_1 lower the level; the x raise it.

The TRIPOD OF THE INSTRUMENT is of very light construction of mahogany and bronze, yet very solid.

The feet are in five parts; four united two and two, and a very strong single one J, which serves for the rough levelling of the bearing-plate. By reason of its special construction this leg, once planted, resists all efforts tending to turn the platform.

FF. Bronze platform with mahogany top, on which the instrument is rested by interposing the small disks, $p.p$.

The platform turns on two bolts and can be fixed in any position by tightening the nuts H H.

l_3. Safety lever, which by means of the scew I and the clamps k k k_2, in one of which an end is fixed, serves to prevent all accidental rotation of the platform; at the same time turning the screw slowly furnishes a means of levelling the platform by using the spherical level L_3. In this operation the leg or branch J, which can be more or less inclined according to necessity, is also useful.

For carrying—the screw I is detached from the clamp, the lever is raised and the plate turned into the plane of the legs.

g. Screw and spring for fixing the instrument to the base.

X. Head of the screw to be applied to the instrument.

X_1. Nut for tightening the spring. Before closing X_1 the instrument should be centered over the axis of the stake or point on the ground, of the station, if that is necessary.

$N.$ $B.$ On special order can also be furnished the form of tripod known as "*à l'anglaise*," like that of the intermediate and small model cleps.

pp'. Illuminating prisms.

The lighting of that portion of the graduation to be read by the microscopes might be obtained by simple windows in the sides of the circle-box. Nevertheless very recently the makers have en-

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deavored to render the lighting as complete as possible in every position by means of a very simple arrangement of reflectors screwed to the sides of the box, to which the light of the sky, or of a lamp, is sent by means of the two illuminating prisms *pp'*. These prisms are pivoted about the central normal to their supporting faces, in such a way that they are able to seek for light, so to speak, in the entire vertical plane. This arrangement is a very advantageous one at night, or in mines, for by turning the faces of the prisms toward the observer who is reading the microscopes, he is able to illuminate the graduations with the lamp which he holds in his hand, without being inconvenienced by the flame of the lamp itself.

ELECTRICAL ENGINEERING AT COLUMBIA UNIVERSITY.

FRANCIS B. CROCKER.

The new buildings of Columbia University are located at 116th Street, between the Boulevard and Amsterdam Avenue, on the highest part of Morningside Heights, midway between Grant's Tomb and the new Episcopal Cathedral, commanding a view of the Hudson on the west and the Harlem River on the east. Thus situated in a great metropolis, the University secures the manifold advantages which that fact gives it, and at the same time is sufficiently lifted above the hurry and noise of the city to have the collegiate atmosphere. This effect is still further increased by the fact that the grounds between the various buildings form a plateau about twenty feet above the level of the grounds and streets outside of the group of buildings. By this arrangement great economy of space is secured, since it gives two more floors to each of the buildings situated around the edge of the plateau, their basements and sub-basements being above the level of the surrounding grounds. The raised level between the buildings also enables tunnels to be constructed which connect the various buildings with the central power plant in the University building. Through these tunnels all the steam and gas pipes, as well as the electrical conductors, are carried and the cartage of coal, ashes and supplies takes place.

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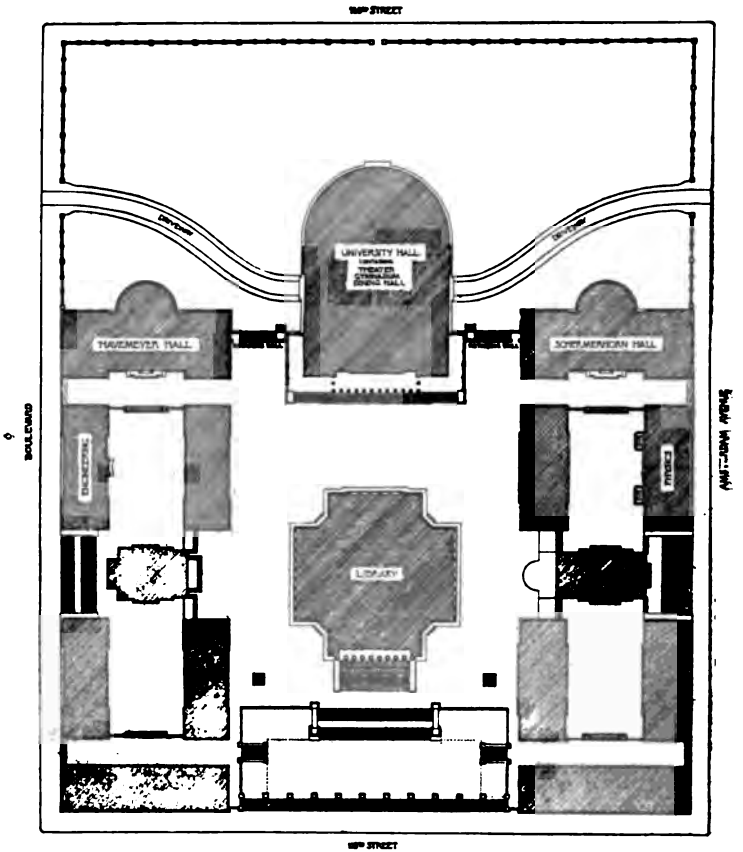
In this way these important practical matters are very conveniently carried on below ground as far as the College is concerned, but at the same time above the street level. Each building is provided with an elevator, chiefly used for carrying apparatus and supplies to and from the various laboratories, lecture rooms and museums. Thus, it is an easy matter to transport even heavy ap-



PLAN OF THE NEW BUILDINGS AND GROUNDS
COLUMBIA UNIVERSITY

paratus from any room in the University to any other room. To still further facilitate this service, the door sills are entirely omitted in most of the rooms, so that a truck can be run about the buildings without jarring that which it carries, enabling apparatus to be arranged in the laboratory for use in the lecture rooms.

The location of the various buildings at the new site are shown

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in the general plan,* the magnificent Library presented by President Low being the central one and easily accessible from all the others.

University Hall is the other general building, containing the power plant, gymnasium, academic theatre, etc. There are also four new buildings respectively devoted to Engineering, Chemistry, Natural Science, and Physics. Two old buildings will be used for the present by the Departments of Ancient and Modern Languages, and Mathematics.

The Schools of Law, Political Science and Philosophy are located in the Library Building, bringing them within convenient reach of the books upon which they are especially dependent. The Medical School will remain at 59th Street, between 9th and 10th Avenues, where it is well provided with buildings and equipment. All the other departments of the University, including Barnard College and the Teachers' College, which are affiliated with it, have removed to the new site.

The Engineering Building, with its annex, contains the Departments of Electrical, Mechanical, Civil and Mining Engineering. Havemeyer Hall, the Chemistry Building, is the home of one of the largest and best equipped chemical schools in the world, having been designed by Professor Charles F. Chandler and the officers of his department after a careful study of the principal colleges and technical schools in this country and abroad. The Departments

* Only those buildings designated by names have already been erected.

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of Metallurgy and of Architecture are temporarily housed in the Chemistry Building, which has more than sufficient space for present needs. Schermerhorn Hall, the Natural Science Building, contains the Departments of Geology, Mineralogy, Biology, etc., and their extensive collections. The Physics Building, which also accommodates the Departments of Mechanics and Astronomy, is designed and equipped according to the most modern methods for teaching and investigating physical science.

It is a striking fact, characteristic of modern tendencies, that all four of the new buildings, besides the Library and University Buildings, which are used for general purposes, are devoted entirely to scienee; and three of them are especially important in their relation to Electrical Engineering. Hence, the Course in Electrical Engineering at Columbia, which has already gained for itself a prominent position in electrical education in this country, has been materially benefited by the removal of the University to its new site. The principal improvements consist in a considerable extension of space and equipment in the Electrical Engineering laboratories, as well as in those devoted to Mechanical Engineering, Physics and Chemistry.

The regular four-years' course, leading to the degree of Electrical Engineer (E.E.), is designed for the education of professional electrical engineers who intend to devote themselves to the practice of this profession, either as teachers in colleges and scientific schools, or as engineers, managers or experts in manufacturing or other industrial enterprises.

The course of instruction includes not only all important branches of theoretical and applied electricity, but also the other collateral sciences, which have been found by experience to be required by the electrical engineer, such as mathematics, physics, chemistry, drawing, analytical mechanics, mechanical engineering, including a thorough course in steam and other engines, as well as transmissive machinery and shopwork; general engineering, including construction in masonry, iron, steel and wood, also forms part of the course.

Hence the graduate in the course in Electrical Engineering is provided not only with a thorough knowledge of the principles and practice of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for every demand that is likely to be made upon him in after life in connec-

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tion with his profession, and will also enable him to become an investigator. The instruction is by lecture, recitation, laboratory, work-shop and drawing-room practice, with periodical examinations. Special attention is given to new methods and forms of apparatus in order that the student may be brought fully abreast of the rapid progress of electrical science and practice. Frequent visits are made to the numerous electrical factories, stations and other establishments in and about New York.

The offices, laboratories, lecture and other rooms of the Electrical Engineering Department are in the south end of the Engineering Building. In the sub-basement are located the storage battery and photometer rooms; the former will contain a battery of 70 cells, to be used for efficiency and output tests and also as a source of steady potential and current. The photometer room is equipped with all necessary apparatus for determining the candle power of arc and incandescent lamps as well as other sources of light. In the basement are situated the two machine laboratories, the larger containing the direct current machinery, while the smaller accommodates the alternating current apparatus. These are shown in cross section and plan in the accompanying illustrations. In the direct current laboratory a 50 H. P., high-speed steam engine drives two lines of shafting, carrying pulleys controlled by friction clutches, to which the various machines are belted. The arrangement of the engine and shaft is such that two dynamos of 30 kilowatts each can be connected to the engine, or either or both of the two machines may be used as motors to drive the line shaft, the current being obtained from the electric light and power plant of the University. In this way the breaking down of the motive power is rendered almost impossible and an excellent demonstration of the two methods of driving is made.

The smaller machines are mounted upon two long heavy tables, as represented in the illustrations, which brings them to a convenient height and affords space for instruments, note books, etc.

The various dynamos which are belted to the line shaft include examples of 115, 230 and 500 volt constant potential generators, constant current arc-lighting dynamos and other typical machines. Several types of stationary and railway motors, as well as motor dynamos, are also placed in this room. Machine and hand tools are provided in one corner of this laboratory for making and repairing apparatus, attachments, etc. Complete sets of ampere and

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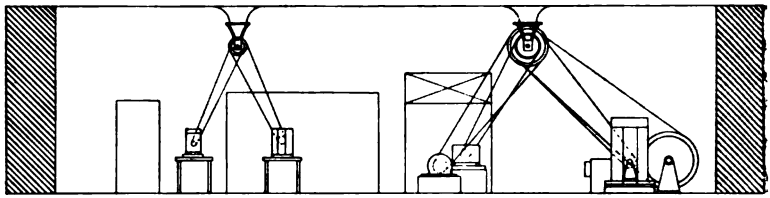

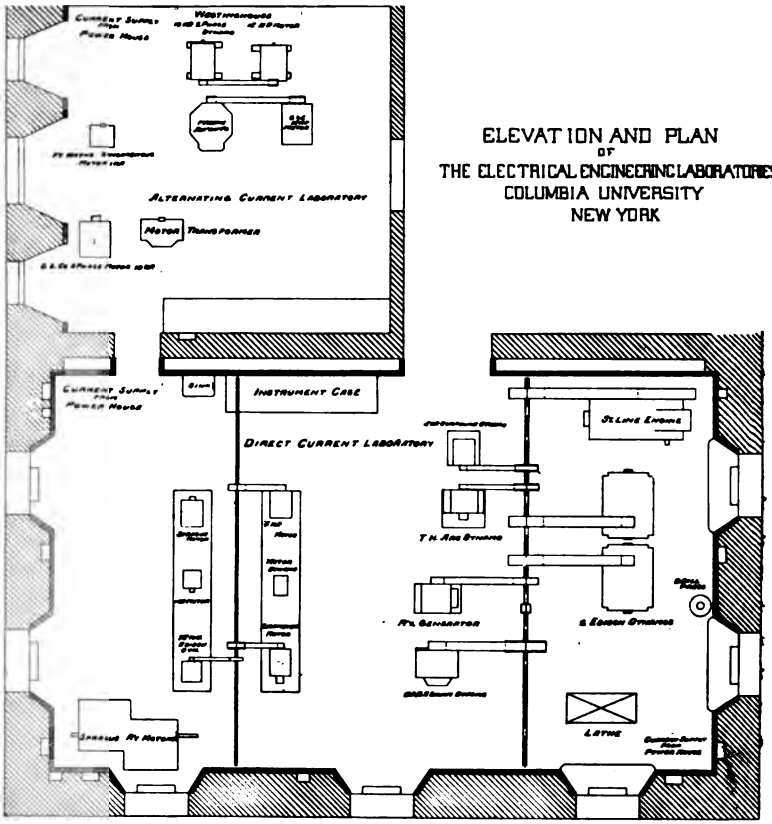

volt meters, speed indicators, transmission and absorption dynamo meters, etc., are available for testing the various dynamos and motors.

In the other machinery laboratory the alternating current apparatus is placed, including single and polyphase generators, induction and synchronous motors, as well as various types and sizes of transformers. Each generator is driven by its own electric motor, enabling its speed to be independently regulated.

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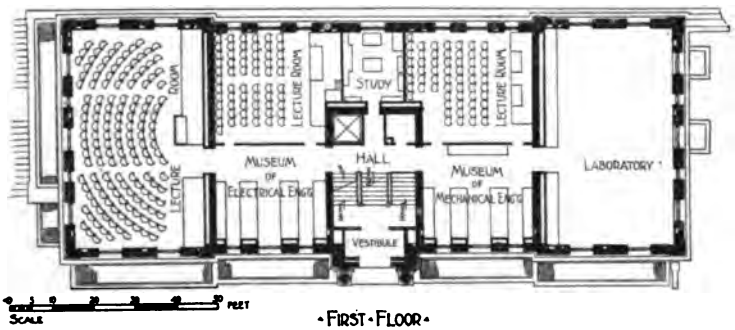
On the first floor are situated the smaller lecture room (seating 70), ordinarily used for class work and the larger lecture room (seating 150) for combined classes. In the Chemical Building, immediately adjoining, a still larger lecture room (seating 350) is available for meetings and public lectures. All of these rooms are provided with an ample supply of electrical energy of different forms as well as gas, water and other facilities to enable experimental demonstrations to be conveniently and effectively performed. For example, dynamos, motors and other apparatus of practical size are shown in actual operation to illustrate the lectures, this being made a special feature of the instruction.



ENGINEERING BUILDING

The museum contains cases for the collection of apparatus, models, materials, etc., relating to electrical engineering. This museum adjoins the lecture rooms so that its contents can be conveniently used for illustration.

On the third floor are located the large instrumental laboratory, the research room and the studies of the officers. The laboratory contains a number of tables on which the instruments are permanently set up ready for use. These include various forms of galvanometers, ampere balances, standard cells and resistances, apparatus for measuring inductance, magnetic permeability, hysteresis and leakage, laboratory standard volt and ampere-meters, telegraph, telephone and electric signaling systems, thermoelectric and electric heating devices, Röntgen-ray apparatus. The research room is used for special post-graduate and thesis work and is fitted up according to the lines of investigation that are being followed.

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A most important facility is the large and reliable supply of electrical current which is afforded by the central power-plant of the University. This consists of boilers having an aggregate capacity of 2,000 H. P., two low-speed engines directly connected to two dynamos of 275 H. P. each and two high-speed engines directly connected to the dynamos of 100 H. P. each. This electrical generating plant, having a total capacity of 750 H. P. and illustrating the latest practice in electrical engineering, furnishes current for electric lighting and for driving the motors and fans used in ventilating all of the buildings. Special conductors are also laid to convey to all of the laboratories and lecture rooms of the Electrical Engineering Department an ample supply of current for experimental work.

The Physical Laboratories and lecture rooms occupy four floors of the Physics Building on the eastern side of the University grounds. The building is supplied with all ordinary conveniences, including electricity for power and light, compressed air and steam. There is a vertical shaft 95 feet high with gas, electric and water outlets at every ten feet. In the sub-basement a constant temperature room is placed 12 feet below the surface of the ground. A platform on the roof is available for meteorological observations, an instrument room being directly below. There are two lecture rooms, a library, an apparatus room and laboratories of various kinds.

The general elementary laboratory includes in its equipment linear and circular dividing engines of various designs. For measurements of mass there are provided balances with weights, specific gravity apparatus, hydrometers, aerometers and the various forms of vapor-density apparatus. Standard barometers, pendulums and apparatus for studying elasticity are provided; also apparatus for the study of sound.

Thermometers and apparatus for their calibration, and determination of zero and boiling points, are supplied; also apparatus for determination of coefficients of expansion, for latent and specific heat, and calorimetry.

The optical rooms are furnished with spectrometers of different designs, spectroscopes, telescopes, microscopes, sets of lenses, prisms and gratings, optical benches, photometers and apparatus for colorimetry, polarized light and spectroscopy.

In the rooms devoted to electricity are galvanometers of various

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patterns, high and low resistance, ballistic and damped; electrometers, magnetometers, standard cells, resistances, rheostats and bridges of all types; condensers, batteries, keys, arc and incandescent lamps, amperemeters and voltmeters.

The Mechanical Engineering Department.

The Mechanical Engineering Department is located in the Engineering Building and in the annex, the space and equipment provided for it being greatly increased at the new site. This improvement is made not only on account of the importance of this branch in the Electrical, Civil and Mining Engineering courses but also because regular courses in Mechanical Engineering have now been opened at Columbia for the first time, the space at the old site not having been adequate for the purpose. The department has the following equipment:

The workworking and machine shops are located in the Teachers College, 120th Street. For woodworking there are carpenter's benches with their kits of tools, speed lathes, saw benches and planers. For forge and blacksmith work there are forges with anvils and tools, a Bradley hammer and a Billings and Spencer drop-press. For metal working there are engine-lathes with swing from twelve inches to twenty inches, planers, shapers, drill-presses, a universal milling machine, universal grinding machines and a Jones and Samson turret-lathe.

The testing laboratory is equipped with high grade testing machines for tensile, transverse, torsion and compression tests. Their designs are of diverse types to give wide experience in handling, and they are fitted with the best and newest appliances for observing and recording deformations of test-pieces. The Emery Testing Machine of 150,000 pounds' capacity is used as a standard of reference.

The Mechanical Engineering Laboratory is well supplied with dynamometers of transmission and absorption types, with oil-testing appliances, speed recorders, tachometers, weighing and measuring apparatus, anemometers, gauge testers and the like, and representative machines and mechanisms for calibration and tests of efficiency.

The Steam Engineering and Motive Power Laboratory has an extensive series of indicators, with appliances for calibrating and standardizing them, test-gauges, thermometers, calorimeters, pyrom-

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eters and apparatus for boiler and engine tests. A triple expansion steam engine of the Reynolds-Allis-Corliss design is arranged to work as an experimental steam engine by making it a three-stage air compressor when so operated, and having all facilities for the accurate measurement of efficiencies. A full line of boiler-feed-injectors is mounted for display and experiment. Steam engines of various other types, steam pumps, a ten-horse-power Le Laval steam turbine, hot-air and gas engines are at hand, and surface-condensing appliances as well. The department has also a cross-compound two-stage air compressor; the cross-compound air end with inter-cooler makes a most complete example of applications of thermo dynamic theory to practice. This laboratory is known as the Allis Laboratory in memory of the Edward P. Allis.

The Hydraulic Motors Laboratory contains tanks, weir-notch equipment, gauges, current meters, water meters, and motors for test and experiment. Constant pressure is secured by air-pressure upon the water in a closed tank, thus doing away with a stand-pipe. For heavier pressures, above 100 pounds per square inch, an adjustable accumulator is used. Pumps of large capacity give the necessary quantity of water for orifice tests and other drill in hydraulic engineering. The equipment of this laboratory is presented as a gift to the University, as a memorial of the late Henry R. Worthington, of New York City.

The drawing academies are particularly well lighted and of large extent, and are fitted with the best forms of drawing tables and furniture, as well as extensive collections of patterns, models and illustrative drawings, blue prints, photographs and prints, which are useful as copies and for training in design. Sectional models of actual machines and structual material are abundant, and for the study of projection, stone-cutting and warped surfaces, there is a set of the Ollivier models, in which the elements of surfaces are represented by tense-threads. In connection with the drawing academy is a room for blue printing and other solar work, and a photographic dark room.

The Cabinets or Museum Collections of Mechanical Engineering models of mechanical movements, mechanisms and gearing, also material which has failed in service and under test. Specimens of apparatus and materials for practice are also included.

The Chemical Department occupies Havemeyer Hall, which is

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located at the northwestern corner of the group of buildings. It contains several chemical lecture rooms, fully supplied with apparatus and instruments and all modern facilities for the experimental illustration of the different lecture courses.

The museum of general inorganic and organic chemistry, and of the chemical arts, contains the elements and all their more important compounds; representative sets of specimens of all classes of compounds, materials and products, together with models, pictures and diagrams.

The qualitative laboratory is provided with tables, re-agents, and all the necessary facilities to enable each student to become familiar with the reactions of the different metals and salts. The student is required to repeat all the experiments of the course of instruction at his own table in this laboratory.

The quantitative laboratory is provided with tables, re-agents and all the necessary apparatus and instruments to enable the student to actually execute quantitative analyses.

There is also a laboratory specially fitted up for electro-chemical work.

The theoretical and practical branches of Electrical Engineering are taught by Professors F. B. Crocker and M. I. Pupin and Messrs. G. F. Sever, W. H. Freedman and S. G. T. Townsend.

A STRAIGHT LINE FORMULA FOR CAST-IRON COLUMNS.

SAMUEL OSGOOD MILLER.

The recent tests of cast iron columns by the New York Department of Buildings at Phœnixville, Pa., were the first tests ever made on such large columns, hence they give the first data for establishing a formula for columns of large size. The reports of the Watertown Arsenal for 1887 and 1888 give the results of tests of a series of cast-iron columns that were smaller than those tested by the Building Department, hence the two sets of tests combined give a range of proportions of length to radius of gyration which applies to almost all cases found in common use.

The diagram on page 186 shows the results of the tests at both

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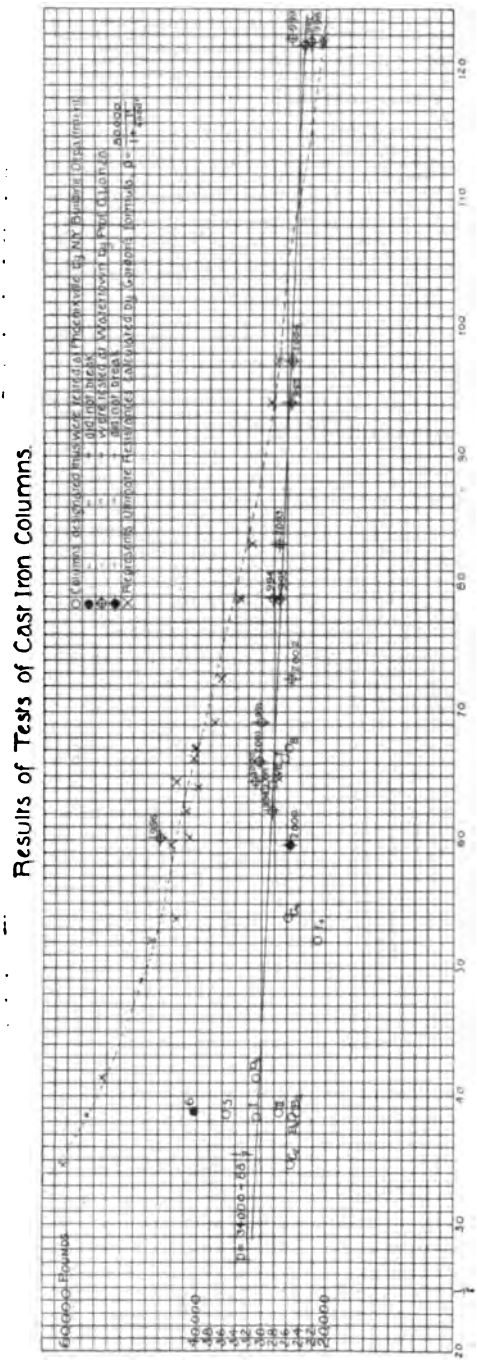

Watertown and Phœnixville with the same numbers or marks used to designate the test columns in the official reports. The horizontal ordinates represent the values of length divided by radius of gyration and the vertical, ultimate resistances in pounds per square inch of section. A straight line is then drawn which represents the mean of the plotted results; the equation of this line is

$$p = 34{,}000 - 88\frac{l}{r},$$

p, being the unit ultimate resistance; l, the length, and r, the radius of gyration; this method of proceedure and notation is similar to that used by Professor Burr, in his "Elasticity and Resistance of Materials," in the determination of a formula for wrought-iron Phœnix columns. The equation then gives the probable resistances of columns, cast of average metal and with average care, within limits of $l \div r = 30$ and $l \div r = 125$. The Phœnixville columns were the prod-

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ucts of four different foundries and the Watertown columns came from an old building undergoing alterations.

The report shows that columns B_2, B_4, C_2, D^*_4, F_4 and G_4 were of poor material, having "blow holes," "foundry dirt," etc., in them; reference to the diagram shows that these results fall below the line, with one exception, while Nos, I., II., 5 and 6 were specially cast, two of them of ordinary iron and two of extra strong iron. It is to be supposed that Nos. 5 and 6 were the columns cast of the best grade of iron, and hence the line should pass below them but above the results obtained from the very poor columns. Tests numbered 7, 8, XVI. and XVII. were on columns of good iron, and it is seen that they group quite close to the line.

The Watertown tests, with one exception, fall very close to the line; the high breaking point of No. 996 is very peculiar, especially as the report states that this column had "spongy metal on one side." Column No. 992 has been omitted from the plot, as section was very irregular; it must be stated that the cross-sections used in obtaining the unit ultimate resistances were the mean sections, and not the minimum, as given in the reports.

An interesting and rather alarming comparison is made by calculating for each column the ultimate resistances by Gordon's formula, using the coefficients prescribed by the New York building law, which is

$$p = \frac{80{,}00}{1 + \frac{l^2}{400\, d^2}},$$

and plotting the results directly over the experimental breaking points, this has been done in the accompanying diagram, and an average line drawn through the points. These calculated results do not plot in a smooth curve, as the variable in Gordon's formula is only correct for solid columns, while in the diagram the variable used $\left(\frac{l}{r}\right)$ is general for any section. It is seen that for values of $l \div r = 30$ to 40 Gordon's formula gives results appoximately twice as large as the experiments; the lines then converge with increasing values of $l \div r$ until they cross at 110; above this point Gordon's formula gives results lower than the experiments.

The following tabulation gives the data used in making the diagram.

*This column is designated as D_4 in the official report.

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Results of Tests Made at Phœnixville, Pa., by New York Department of Buildings.

Col.	Diameter (d)	Thickness of metal.	Area in sq. in.	l	Exp. Breaking load per sq. in.	Rad. of Gyr. (r)	$\frac{l}{r}$	$\frac{l^2}{d^2}$	Breaking stress by $p = \frac{80{,}000}{1 + \frac{l^2}{400 d^2}}$
I	15″	1″	43.98	190¼″	30,830	4.962	38.341	160.86	57,055
II	15	1⅛	49.03	"	27,126	4.92	38.668	"	"
B2	15	1⅛	49.03	"	24,434	4.92	"	"	"
B4	15⅛	1⅛	49.48	"	25,182	4.965	38.318	"	"
(5)	15	1 1/16	50.91	"	35,435 (Did not break)	4.936	38.543	"	"
(6)	15	1 3/16	51.52	"	40,411	4.899	38.834	"	"
XVI	8	1	21.99	160	29,604	2.50	64.00	400	40,000
XVII	8	1 3/16	22.87	160	28,229	2.486	64.361	"	"
(7)	6 1/16	1 9/16	17.64	120	25,805	1.786	67.189	391.8	40,414
(8)	6 3/32	1 7/16	17.37	120	26,205	1.805	66.483	387.8	40,619
G4	8	¾	17.083	147¾	25,969	2.741	53.903	341.09	43,180
F4	9	1	25.133	150.	21,181	2.872	52.226	277.77	47,214
D4*	12	1	34.588	162	30,810	3.906	41.475	182.25	54,960
C2	14	1	40.841	159¾	25,401	4.609	34.661	130.20	60,355

Results of Professor Lanza's Tests made at Watertown, Mass.

Col.	Diameter (d)	Thickness of metal.	Area in sq. in. (A)	Length in ins. (l)	Exp. Breaking Load per sq. in.	Rad. of Gyr. (r)	$\frac{l}{r}$	$\frac{l^2}{d^2}$	Breaking stress by $p = \frac{80{,}000}{1 + \frac{l^2}{400 d^2}}$
2,000	8.695″	1.36″	31.34	157.	(Did not break), 25,720 (Did not break),	2.631	59.67	326.04	44,075
2,001	7.92	1.3075	27 15	156.9	30,380	2.371	66.17	392.44	40,381
2,002	7.17	1.16	21.88	156.9	25,470	2.164	72.56	478.95	36,175
2,003	6.35	1.13	18.52	156.9	27,210	1.888	83.1	610.53	31,665
2,004	5.65	.8175	12.95	156.4	25,100	1.712	97.49	766.26	27,403
990	6.8725	.9813	18.16	131.55	28,226	2.11	62.34	366.41	41,750
991	6.885	.9525	17.69	146.75	30,000	2.12	69.2	454.31	37,455
993	5.37	.91375	12.79	151.5	25,440	1.61	94.1	795.85	28,425
994	5.43	.9063	12.86	128 6	28,080	1.63	78.89	560.98	33,299
995	5.45	.90	12.865	129.5	27,360	1.64	78.81	564.65	33,172
996	6.61	.65875	12.32	127.6	45,940	2.12	60.20	372.67	41,415
997	3.475	.875	7.15	118.5	23,118	.97	122.1	1162.43	20,480
998	3.48	.8825	7.14	118.75	22,130	.97	122.4	1164.45	20,454
999	3.48	.905	7.32	118.4	25,060	.965	122.7	1157.60	20,544
1,000	4.575	1.0113	11.32	84.62	30,992	1.31	64.6	342.14	43,119

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SYSTEM IN THE LOCATION OF MINING DISTRICTS.

THEO. F. VAN WAGENEN, E. M.

I desire, through the medium of the QUARTERLY, to call attention to some interesting facts as to the relative situation of those localities in the Western United States where metalliferous ores occur, and to that end have prepared the accompanying map, which covers the country from about the 102° of west longitude to the Pacific. This area embraces all of the distinctive mining States and Territories, and the region of the Black Hills in South Dakota. A vast amount of detail usually found on maps, such as minor political subdivisions, commercial towns, parallels of latitude and longitude, names, etc., has been omitted, so as to display more clearly the drainage system and the mining districts; and it is believed that both of the latter features are shown with as great accuracy as is possible upon a map of such small scale. The writer has partially completed maps of each State upon a much larger scale, showing the same features in greater detail and with more accuracy.

It will at once be observed that the mining localities are not scattered irregularly over the country, but are situated along 10 belts, all of which have a general N. E. and S. W. trend, are roughly parallel to each other, traverse the region between the Plains and the Ocean like gigantic lodes, and are separated by barren areas quite as extensive as, if not larger than themselves. As a genuine effort has been made to locate all the mining districts of the West (though less than half are marked on the present map) these barren localities are really barren, and are not merely unprospected or unprofitable. I may also add that the investigation has been pushed some distance into both British Columbia and Mexico with the result that so far each belt of rich and barren territory continues in the same line. In Central Nevada there appears a short and narrow belt, between the two adjacent ones, which may more properly be regarded as a connection, and around the mouth of the Colorado River two belts appear to unite.

Although all these great lodes (if they may be so considered) are approximately parallel, yet when No. 1 in the northwest is compared with No. 10 in the southeast, a distinct divergence is

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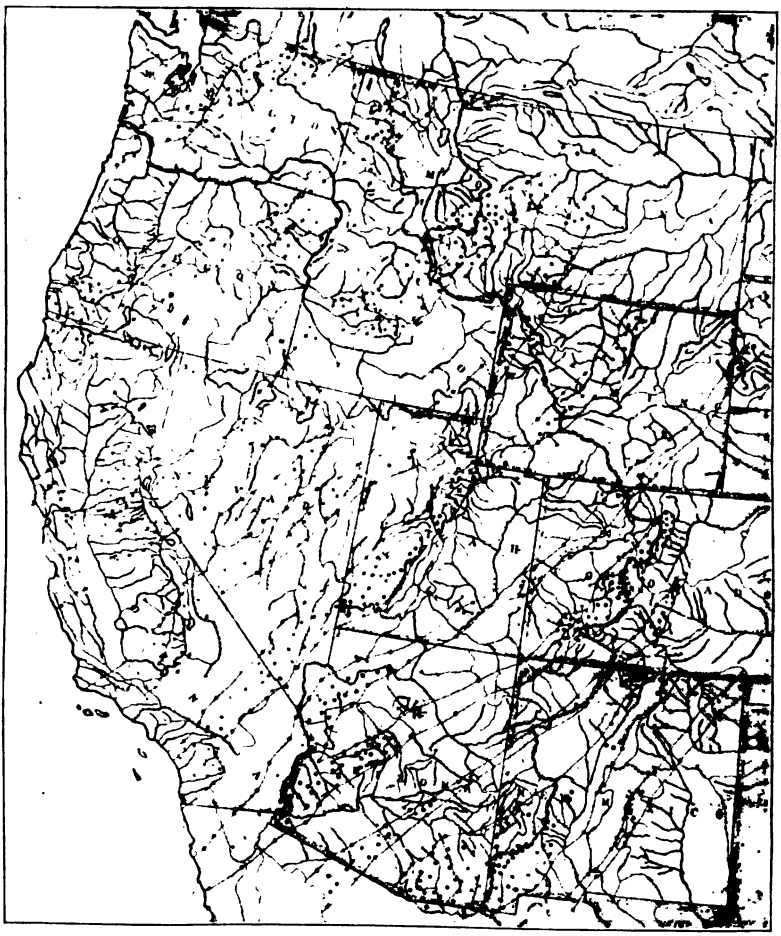
apparent; and if the central line of each be considered its course, the conclusion is that each lode departs more from a true N. and S. line than its neighbor to the eastward, and finally that all follow in a general way the curves of the lines of magnetic variation. I am



of the opinion that when the problem is thoroughly worked out it will be found that the axes of all will be identical with mean magnetic curves.

The subject of mineral belts is not a new one. R. W. Raymond, Clarence King, J. F. Kemp and several others have at different times called attention to the phenomena in various ways,

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but I am not aware that any have mapped them along the courses here shown, or suggested their possible connection with terrestial earth currents. The mere fact of approximate parallelism is simply graphically interesting, but if their coincidence with the curves of magnetic variation can be clearly and unmistakably proven, it wovld not only be highly probable that electrical energy in one form or another has had much to do with the deposition of metalliferous ores, but it would be a fair conclusion that in the region of the Magnetic Pole on the north shore of Hudson Bay, where the belts converge, excessive mineralization exists. Further, if system in the fissuring of the earth's crust by mineral veins is clearly shown in the Western United States, the same system will most certainly be found all over the globe.

So far as the present showing goes, some economical conclusions seem to be warranted, which can be briefly stated as follows:

1. That geological formations do not necessarily constitute a guide to probable mineral deposits. For, between the mineralized zones shown on the map are vast areas of archean, metamorphic and eruptive rocks (in which it is generally assumed metalliferous deposits occur) that are wholly free from ores; while within their limits not only are these rocks well impregnated, but the mineralization in many places has extended to limestones, sandstones and slates of very recent age.

2. That the mineralization and fissuring of the earth's crust has not been connected with, and is not one of the results of, the elevation of mountain ranges. For the facts appear that the lines of fissures cross the lines of divides at all conceivable angles. To make this clear, the continental divide is strongly displayed on the map by two parallel broken lines with one continuous and lighter line between, and all other high ranges by one broken and one continuous line, while the subsidiary divides are marked only with the fainter continuous line.

3. That mineralization is an older phenomenon than mountain range formations, as might naturally be expected if it has any connection with the curves of magnetic variation. For, where the lines of fissuring are locally approximately parallel with the crest of a prominent divide, the axis of the belt is visibly flexed. This feature is clearly shown at a number of points upon the large scale maps in progress in the writer's office.

4. Certain localities apparently promising, but outside of the

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belts, may be definitely abandoned by the prospector; while others within their limits should receive more careful investigation, even though surface indications are not attractive. For, if there are definite and continuous lines of fissuring and mineralization, these will at places be covered by rock or alluvial formations of recent date, or capped by volcanic overflows, and yet be sometimes accessible artificially or through deep erosion. An instance of this latter condition is found in parts of the Cañon of the Colorado, which cuts for over 100 miles through the course of Belt 6.

The writer hopes gradually to be able to complete his more detailed maps, and to call attention (with their aid) to certain peculiarities of mineralization or rather metallization in some of the Belts, which are at least interesting, and which may have some bearing on the genesis of ore deposits in general.

PHYSICAL TESTS OF NEW YORK SHALES.*

BY HEINRICH RIES, PH.D.

With the great expansion in the manufacture of clay-products with a vitrified or impervious body, such as paving-brick, roofing-tile, sewer-pipe, etc., the producers of this grade of wares have naturally looked about for some abundant material which would give the best and cheapest results. The requirements of such a material are that it must burn to a hard, impervious body at a moderate temperature, and secondly that the difference in temperature between the point of vitrification and viscosity must be sufficiently great to permit the clay being heated to the one stage without damage of running into the other.

It has been found that shales frequently answer these requirements better than other clays and they are consequently much used. On account of their high percentage of fusible impurities they generally burn easily to a dense body, and when ground and mixed with water their plasticity is often very strong. If the ground shale happens to be too lean, that is, lacking in plasticity, this can often be easily remedied by the addition of some plastic

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clay; or again the fusibility may sometimes require lessening by the addition of more refractory shale or clay, often obtainable from the same mine. The difference in temperature between vitrification and viscosity will vary, being as little as 50° Fahr. in some calcareous shales, and 200° Fahr. in others. While the nearer it approaches 200° Fahr. the better it is,* still many good vitrified wares are made from clays in which the difference between vitrification and viscosity is only 100° Fahr.

SUMMARY OF PHYSICAL TESTS.

Locality.	Character of Shale.	Per cent. Water Added.	Plasticity.	Av. Tensile Strength. Lbs. per sq. in.	Max. Tensile Strength. Lbs. per sq. in.	Shrinkage in Drying.	Shrinkage in Burning.	Degrees Fahrenheit.		
								Incipient Fusion.	Vitrification.	Viscosity.
Jamestown.	Gritty	18.5	Lean	16	20	4.5%	7.5%	1950	2050	2200
Angola.	Fairly smooth	21.4	Mod'te	91	95	4.0%	10%	1900	2050	2200
Hornellsville.	Gritty	20.	Lean	34	39	2.7%	5.3%	1900	2050	2200
Alfred Centre.	Fairly smooth	22	Mod'te	61	62	4%	9%	1900	2050	2150
Cairo. Mixture Clay and Shale.		23	Good	77	100	4%	9%	1900	2050	2150

In the southern half of New York State are great beds of shale of Hamilton and Chemung age. These beds extend from the Hudson River westward to Lake Erie, and the northern boundary of the area underlain by them follows closely a line connecting Albany and Buffalo. The Hamilton shales and interbedded sandstones form a belt averaging about 14 miles in width just south of this line, and the Chemung shales extend from the southern boundary of the Hamilton half way to the southern edge of the State. In the central and westward portion of the area they are especially argillaceous, but towards the east the shales are frequently quite siliceous.

At present these Devonian shales are utilized at Angola, Jewettville, Hornellsville, Alfred Centre, Corning and Cairo; the products made from them, including paving-brick, sewer-pipe, roofing-tile, terra-cotta, dry-pressed brick and drain-tile.

*Wheeler claims it should not be less than 200°Fahr. Vitrified Paving-Brick, Indianapolis, 1895.

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Recognizing the probable extensive use of these shales in the future, Prof. James Hall had the writer make a series of physical tests of these shales from several of the localities, and the results of these tests are given in tabulated form above. In the case of the shale from Cairo the material is so siliceous that when used by itself it is of little value, but the addition of plastic clay makes a very pasty mixture, as shown by the fair tensile strength which the air-dried briquettes exhibit.

THE FAN PUMP.

A SPECIAL INSTANCE OF ITS USE FOR MILL WATER SUPPLY.

By F. C. HOOPER, Met. E.

While making some experiments in concentration of ores in 1893 there was added to the questions already in hand that of increasing the water supply during the dry months of July and August, when the operations were approaching a commercial basis.

Up to this time the supply had been obtained from a stream a short distance from the mill and one hundred feet above its roof. Other than this the only available supply was a swamp, two hundred feet distant and twenty-five feet below the required water level in the mill. A short dam was built at a convenient point to confine the water and form a basin to settle the slime and sand so that the water could be used again and again. Although the operations were getting beyond an experimental stage, it was necessary to save all possible expense until all stages were successfuly solved. Therefore, at this point it was, first, a question of selecting the cheapest, and next, the best method of pumping the water.

Engineers of all kinds are frequently confronted with the "total depravity of inanimate things," but to such difficulties the mining engineer seems to be specially exposed. Remoteness from a distributing center implies not only high transportation charges, but also a lapse of several weeks from the time of ordering to the receipt of supplies. A large assortment of supplies kept in stock will obviate a shut down, but there are times when it seems that

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nothing short of perpetual motion would keep the plant in operation until a new part for some vital point could be secured. If the engineer is not naturally ingenious his bump indicating that faculty will be much enlarged after a few years of Western mill practice.

In the present case the use of a steam pump would have proved a good solution of the difficulty, but its cost was too great. Several other plans were considered, the following being finally adopted. A discarded four-inch discharge fan pump was placed

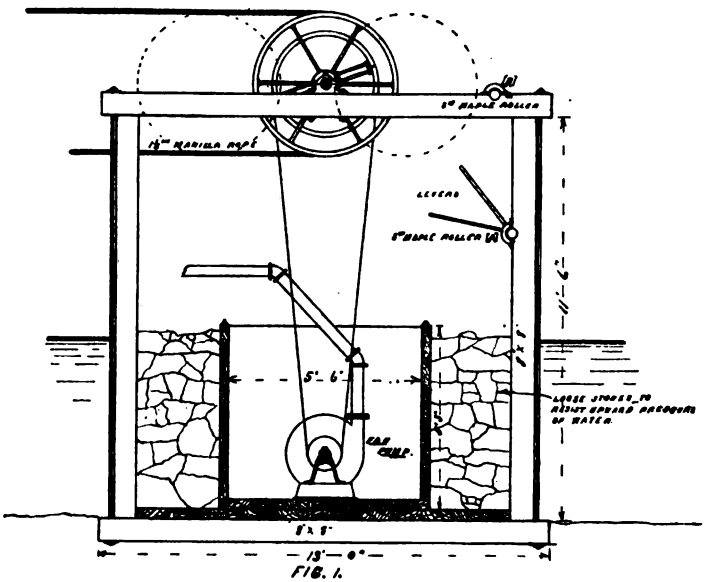

FIG. 1.

in a large water-tight box, the latter being set in the swamp, two hundred feet from the mill, and low enough to be self-priming, to save the cost of foot valves and priming extras. To drive the pump, a counter shaft driven by a rope drive from main line of shafting in the mill was placed on a framework built over the pump. For a transmission cable several lengths of old inch and a quarter manilla guy rope were spliced together. The rope was smeared with hot tallow and graphite to protect it from the weather, and to furnish lubrication for passing around the pulleys. The pump house was made of hewn timber, and the rope pulleys of 1″ boards. Hence the only new material required to secure a four-inch stream of water was the pipe, which would have been equally necessary in any other solution of the problem.

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During the development of the plant later on the above plan was carried out with more care, and the final arrangement is shown in Fig. 1.

As first constructed, the lack of convenient way to take up the stretch in the transmission rope was the main drawback. This could only be done by taking out the old splices, shortening the rope and making new splices, a procedure both inconvenient and hard on the rope.

In Fig. 2 are shown the fixed pulleys, [*A*] and [*B*], and the transmission rope.

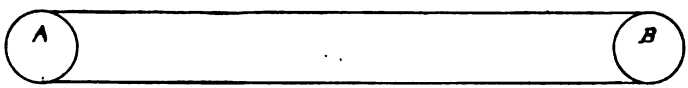
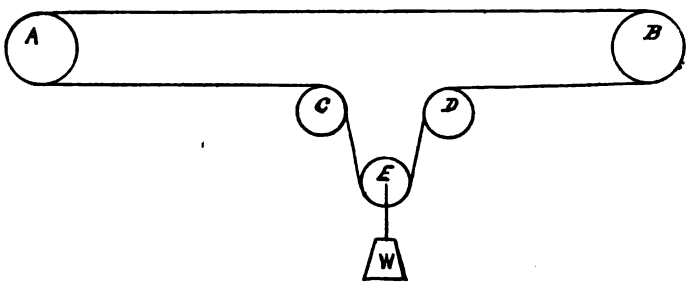


FIG. 2.

As the life of the rope bears an inverse ratio to the number of pulleys around which it travels, the system indicated would be a good one were it not for the stretch of the rope. To overcome the latter difficulty, the method shown in Fig. 3 is often employed.

FIG. 3.



[*A*], [*B*], [*C*] and [*D*] are pulleys on fixed shafts. [*E*] is a movable pulley to which a weight [*W*] is attached to keep a uniform tension on the rope. The wear of a transmission rope is not due to the longitudinal pull, but principally to the slip and friction of the fibers upon one another when bending around a pulley. Hence, as stated above, the greater the number of bends, the greater the wear of the rope.

To avoid this extra wear the arrangement shown in Fig 2 was adopted, except that the shaft carrying pulley [*B*] was made movable.

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In Fig. 1 the movable rope pulley is shown on the countershaft above the pump, with the wooden pulley for driving it. The 8x8 timbers, which support the countershaft, are slotted to allow a longitudinal movement of the bolts holding the shaft bearings. This permits the pulleys to occupy any position from the extreme left to the extreme right, as indicated by the dotted lines in Fig. 1. When a new rope is put on the shaft and pulleys are moved to the extreme left the rope will then have its minimum length. To take up the stretch of the rope which becomes necessary about every six or eight weeks, the loose ends of two chains which are fixed to roller [*A*] are passed over roller [*B*] and attached to each end of the countershaft. The nuts of the bolts holding the shaft bearings are then loosened, and the slack rope taken up by winding up the chain on roller [*A*] by means of the movable levers. A new splice in the rope is necessary only when the rope becomes slack and the pulleys are at the extreme right.

It requires no argument to prove that a pump driven directly from a main line of shafting is more economical than a steam pump. The expense for renewal of worn parts is small and confined almost entirely to the transmission rope. The pump is still doing services and its use gives increased satisfaction.

THE CONDITION IN WHICH ZINC EXISTS IN SLAG.

By MALVERN WELLS ILES.

In a valuable article written by Dr. F. L. Bartlett, entitled "The treatment of zinc-lead sulphide ores" for the Mineral Industry for 1896, we find on p. 629 this somewhat startling statement:

"The writer's experience in smelting zincy ores does not agree with that of some other metallurgists in regard to the form in which zinc enters the slag; he finds that zinc is simply absorbed as oxide, that it does not form any special combination, and does not to any extent replace basic elements. Silicate of zinc is not formed, but oxide of zinc may be absorbed to a large extent, often to 20 or

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25 per cent., especially in basic irony slags, while with acid slags the zinc diminishes in direct ratio to the silica percentage."

The statements that "*zinc is simply absorbed as oxide*" in slags, and that "*silicate of zinc is not formed*," are not only quite startling, but we believe wholly at variance with the well recognized laws of chemistry. We have every reason to believe that when silicic acid is heated up to a high temperature with metallic oxides, a chemical union would result and that silicates would be formed.

A few chemical analyses taken at random is not deemed sufficient to either prove or disprove a law of chemical metallurgy.

Dr. Bartlett's experience in the treatment and handling of zinc ores has been quite extensive, yet a statement without proof is not deemed sufficient in scientific literature.

In the absence of any proof or accurate literature bearing upon the subject of the condition in which zinc exists in slags, we instituted a series of experiments at the laboratory of The Globe Smelter, proving most conclusively that oxide of zinc is not merely absorbed as an oxide in slags and that silicate of zinc is formed. By a very careful study of the tables it will also be seen that oxide of zinc does not play the rôle of an acid to form a zinc spinel.

It gives the writer great pleasure to recognize the assistance given in this study by Mr. Stuart Croasdale, who has carefully prepared the following highly interesting and valuable tables:

Solubility of Chilled Slag in Dilute Sulphuric Acid.

The slag was crushed to 30 mesh., 10 gms. were treated with 300 cc. cold, dilute sulphuric acid and allowed to stand 25 hours. The residue was then filtered off, washed four times with cold water, dried and weighed. The analysis is as follows:

No.	Weight before treatment.	Weight after treatment.	Strength of Acid.	SiO_2	Fe	Mn	Zn	SO_3	CaO	BaO	Al_2O_3	MgO
Original	—	—	—	32.0	21.2	1.0	7.0	—	17.1	2.6	5 0	2.5
1	10 gms.	8.70 gms.	1 %	31.4	18.6	0.7	6.1	3.0	16.6	1.8	4.0	2.5
2	10 "	7.97 "	2.5%	29.4	15.4	0.5	6.0	8.3	15.8	1.9	3.3	1.4
3	10 "	7.02 "	5.0%	23.6	7.8	0.2	4.4	21.9	17.7	2.7	1.3	0.5
4	10 "	7.04 "	10.0%	20.2	3.0	0.0	2.1	35.4	18.1	2.5	0.4	0.2

The above experiments were repeated with slag crushed to 100 mesh, and the following results were obtained:

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No.	Weight before treatment.	Weight after treatment.	Strength of Acid.	SiO_2	Fe	Mn	Zn	SO_3	CaO	BaO	Al_2O_3	MgO
Original	—	—	—	33.6	18.6	2.8	5.4	—	14.1	2.7	6.7	4.8
1	10 gms.	6.74 gms.	1 %	35.0	16.6	2.1	5.0	1.0	14.3	2.6	6.7	3.9
2	10 "	5.81 "	2½ %	32.4	9.8	0.8	3.9	8.9	12.2	3.6	4.1	2.6
3	10 "	3.89 "	5 %	25.8	3.8	0.2	2.5	20.0	14.7	4.8	1.4	1.0
4	10 "	3.83 "	10 %	18.4	1.8	0.0	1.2	28.6	17.8	4.8	0.1	0.4

While it is firmly believed that zinc exists in slags chiefly as a silicate, which we think is proven by the above tables, yet we know that all slags formed by argentiferous lead smelting have mechanically diffused small particles, or prills of matte, and that this matte will invariably contain zinc in the form of a sulphide.

Now, aside from the presence of silicate of zinc, and the sulphide of zinc existing in the matte; we are prepared to state that invariably, there will be found some sulphide of zinc mechanically diffused throughout the slag; this latter statement we have positively demonstrated by blowing compressed air through the molten slag and producing dense white fumes which have been caught and accurately analyzed, giving the following results

16.1 % SO_3
6.9 % Total Sulphur
7.9 % Zinc
Trace Copper
2.5 ounces silver per ton
62.6 % Pb (Fire Assay)
64.0 % Pb (wet determination).

It is believed the chemical elements of the fume arising from Bessemerizing zinc and lead slags are in combination as follows:

1.51 % ZnS.
8.58 % ZnO.
60.94 % $PbSO_4$.
24.07 % PbO.
95.10

The balance, or undetermined (4.90%), is believed to be potash, soda, arsenic, antimony, tellurium and possibly many other elements in variable forms of combination. In this connection it is

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very interesting to note that in all of the many experiments we made the slag fume invariably showed distinct traces of gold. In performing the slag bessemerizing experiments we used compressed air at a pressure of 80 pounds and a suitable exhaust fan. The fumes were strained through both muslin and woolen cloth.

DENVER, November 17, 1897.

POWER CONSUMPTION ON THE LENOX AVENUE CONDUIT ELECTRIC ROAD, NEW YORK CITY.

G. F. SEVER, INSTRUCTOR, ELEC. ENG. DEPT.

It was announced in June, 1894, that the Metropolitan Traction Company, of New York City, would build an open slot electric railway conduit on one of the uptown avenues, in order to give the system a practical test.

In the spring of 1895 this conduit road had been completed and was put into operation, the line extending from 146 Street and Lenox Avenue to 116 Street, along this street westward to Manhattan Avenue, south on this avenue to 109th Street, passing through which, connection was made with the cable road on Columbus Avenue, the total distance being about 2.36 miles. The construction of the roadbed of this line was such, that in case the electric installation proved to be so faulty as to call for its removal, the cable sheaves and necessary equipment could easily be put into the same conduit. For this reason the cost of construction was considerably more than would have been the case if it had been built simply for electric operation. From the cuts, it is apparent how simple the method of construction is, the two conductor rails being supported in place, inside the conduit, by two insulated hangers bolted to the bottom of the slot rail. These insulators are placed 15 feet apart, lengthways of the line, and are so placed at right angles to this, as to bring the two conductor rails 6″ apart. The slot rails have a lip which prevents the surface water from dropping upon the conductor rails and causing trouble from leakage and short circuits.

The plow, suspended from a carrier on the truck frame of the car, passes through the slot and carries on its lower end two cast-

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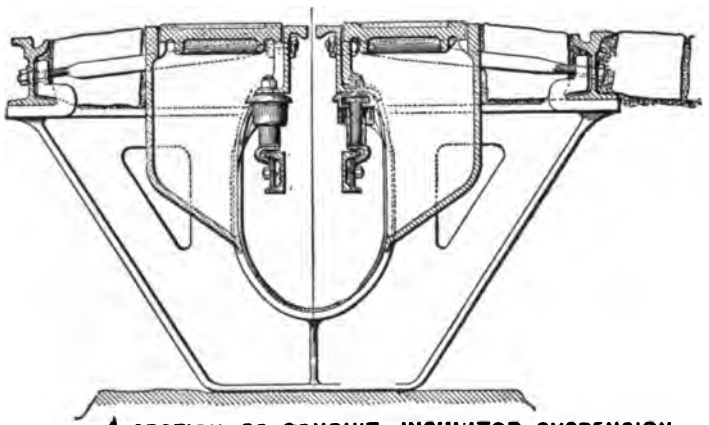
iron blocks, which are pressed against the conductor rails by flexible copper springs. Flat copper strips passing from the car through the plow, connect with these copper springs and iron blocks, forming the means for the current to pass to the controlling apparatus of the motors.

As the successful operation of such a road as this depends absolutely upon the effectiveness of the drainage of the conduit, great pains have been taken to make the connections from the conduit to the sewers large and sufficiently numerous to take care of extraordinary amounts of surface water due to storms or melting snow.

In figure 1 is shown the cross section of the conduit as laid down on Lenox Avenue, the cut illustrating very clearly the relative position of the conductor rails and insulators.



SECTION OF CONDUIT—INSULATOR SUSPENSION.
FIG. 1.

A difference of potential of 300 volts was maintained between the conductor rails when the road was first operated, as it was desired to gradually work up to a higher voltage at some later time if conditions so warranted. This pressure would also be sufficient to develop any serious faults in the insulation of the line and would not be quite so dangerous while making tests and experiments on the line. Since the successful operation of the road this pressure has been raised to that commonly employed upon the overhead trolley roads, that is, 500 volts. The operation of the road under these conditions has been entirely satisfactory both as to absence of trouble from leakage and to economy in the use of power. As

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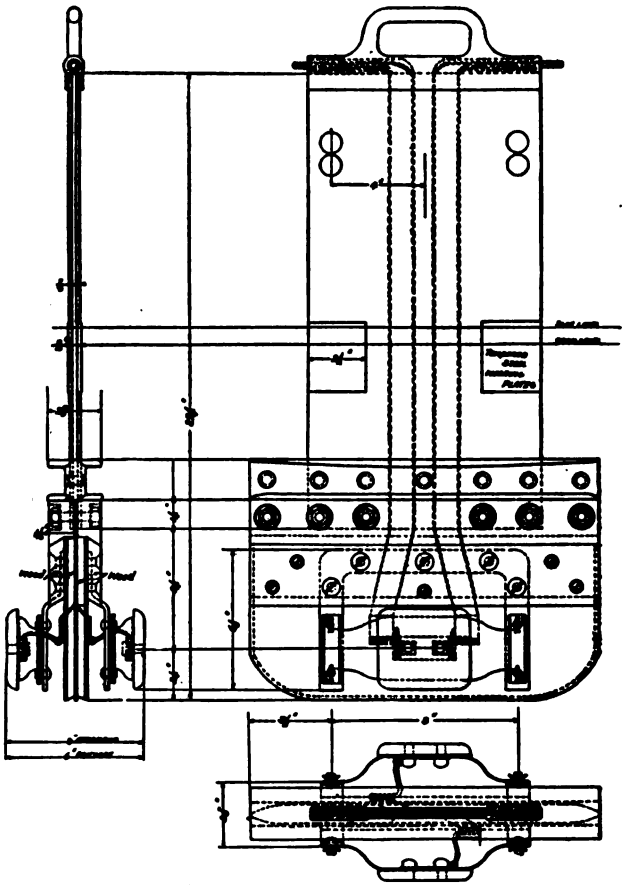
a demonstration of this latter statement, there is given a comparison between a series of tests made in February, 1896, when the road was operated at 300 volts, and a series made in the month of May, 1897, when the pressure had been raised to 500 volts.



CROSS SECTION AND SIDE AND END ELEVATIONS OF PLOW

FIG. 2.

In figure 2 is shown the manner of constructing the plow, this cut illustrating the method of leading the conducting wires from the car to the cast-iron shoes. Figure 3 illustrates the insulator as now employed on the most recent work, also showing the manner of supporting it from the slot rail. The conductor rail, instead of

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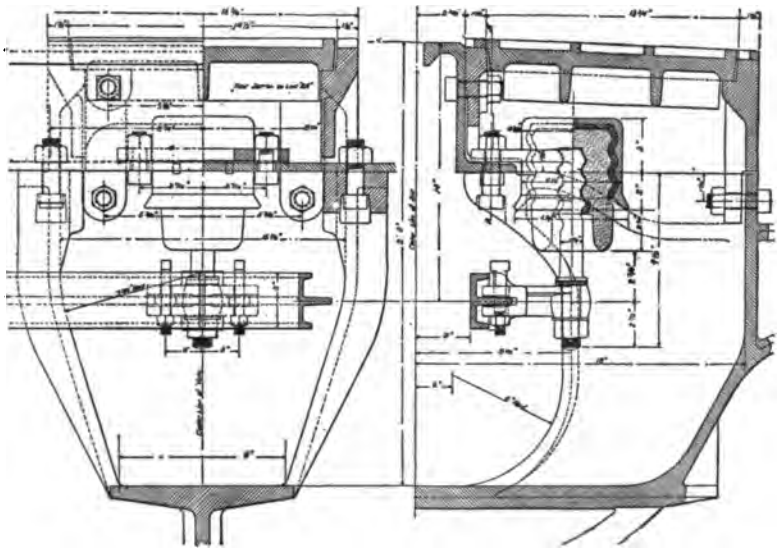
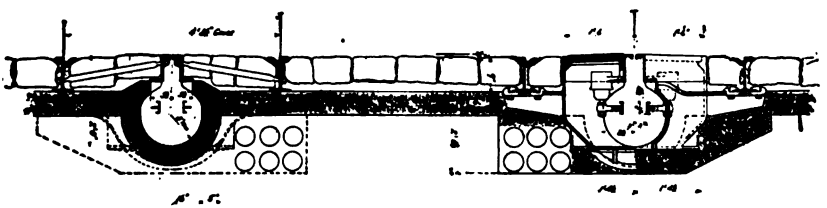


SECTIONS AND SIDE ELEVATION OF INSULATOR

FIG. 3.

being a channel iron, is now made in the section of a *T*, the lips on the head of the section preventing the bending of the rail as the shoe passes over it. Figures 4 and 5 illustrate the cross sections of the roadbed at different places on the line, figure 4 showing the construction between manholes, while figure 5 shows the construction at a large manhole.



CROSS SECTION OF STRAIGHT TRACK CONSTRUCTION BETWEEN MANHOLES

FIG. 4.

It is on account of the highly successful operation of this short experimental piece of line that the company operating it decided to equip many of their other lines with this form of motive power.

The object of the first series of tests was to ascertain the current

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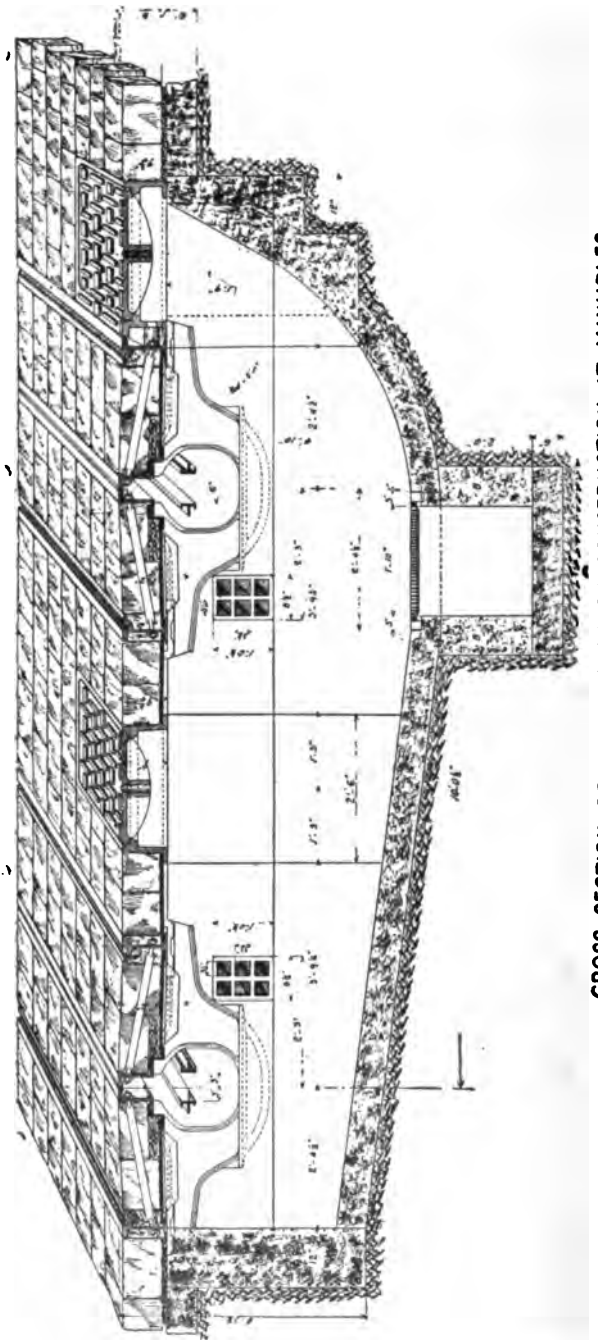

CROSS SECTION OF STRAIGHT TRACK CONSTRUCTION AT MANHOLES
FIG. 5.

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and power consumption under the then existing conditions, the pressure being at that time about 330 volts. The object in making the second series was to ascertain the probable decrease in current and power consumption due to the increase in pressure, this having been raised to about 500 volts. These tests were made in the usual manner, a Boyer speed recorder being connected to the axle of the car, while a Thomson recording watt-meter was so connected as to measure the total watt hours used. Besides the watt-meter, an ammeter and a volt-meter were placed in the circuit and readings were taken from these to serve as a check upon the watt-meter. Readings on the volt and ammeter were taken every five seconds, while readings on the watt-meter were taken every three minutes, so that if anything interrupted the run, the record up to that point could be utilized for the working up of the results. A record of the number of passengers was also kept during the second set of tests. The weather conditions during the two sets of tests were not precisely the same, but this fact would not operate to change the results very materially. A light snow prevailed during the first set, while clear weather existed during the second.

The car employed was of the ordinary closed center-aisle type; 32′–4″ over all; platforms 5′–10″; Peckham trucks; 30″ wheels: 8′ wheel-base; 4′–8½″ gauge; and an equipment of two GE. 800 motors; two "K2" series parallel controllers (with their last point cut out).

During the second series of tests, runs were made to Lexington Avenue, but these have been collected by themselves and are not placed in comparison with the tests made on the Columbus Avenue line. This has been done, as the Lexington Avenue line was not in operation when the first series was made.

The results of the first series are as follows:

Average voltage	323.7	Maximum voltage	410
Average current	31.8	Maximum current	140
Average watt-hours per car mile			1233

The results of the second series are as follows:

Average voltage	475.1	Maximum voltage	540
Average current	19.2	Maximum current	120
Average watt-hours per car mile (six complete runs)			848
Average watt-hours per car mile from station to Columbus Avenue			944
Average watt-hours per car mile from Columbus Avenue to station			752

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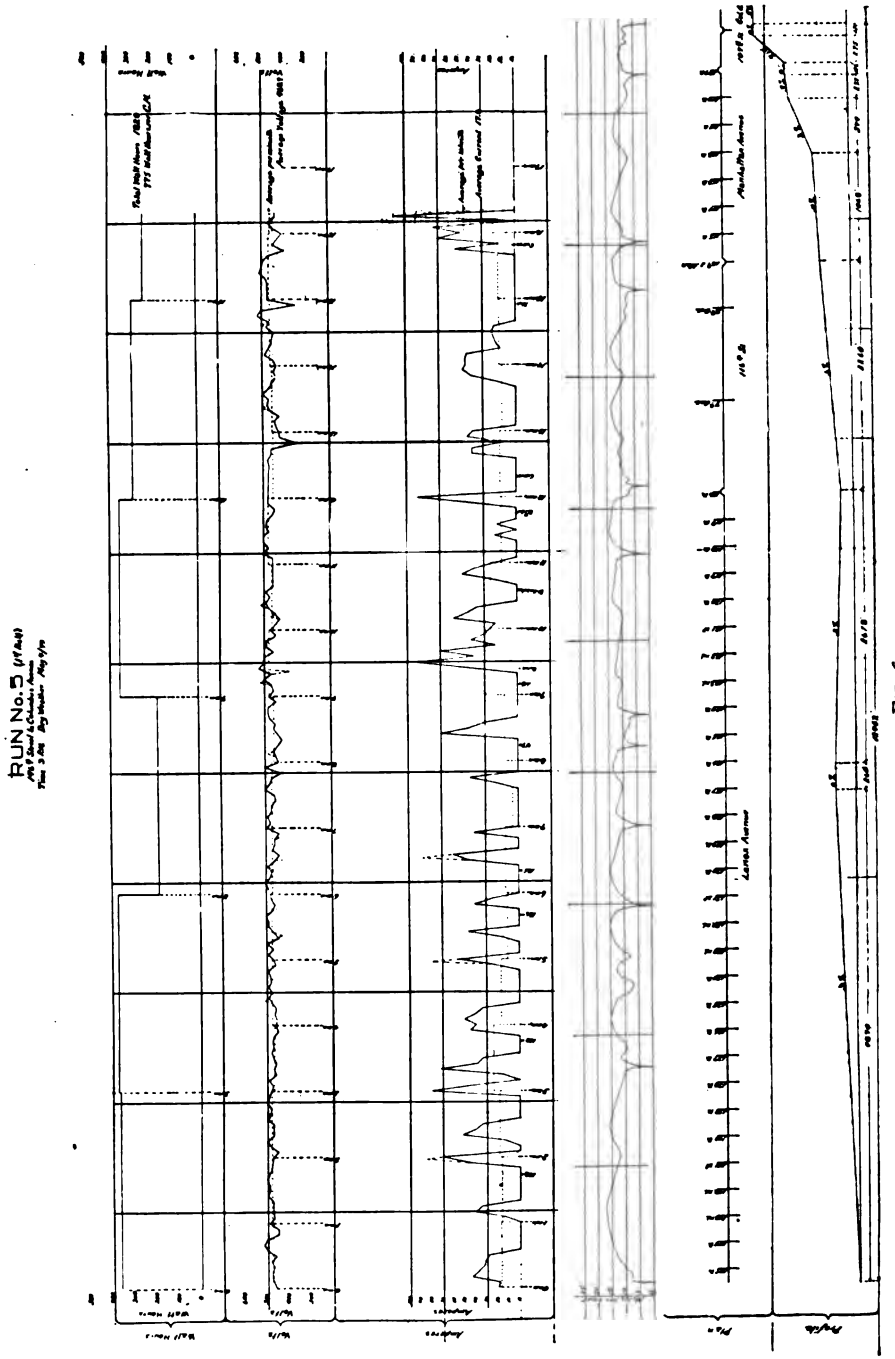

FIG. 6.

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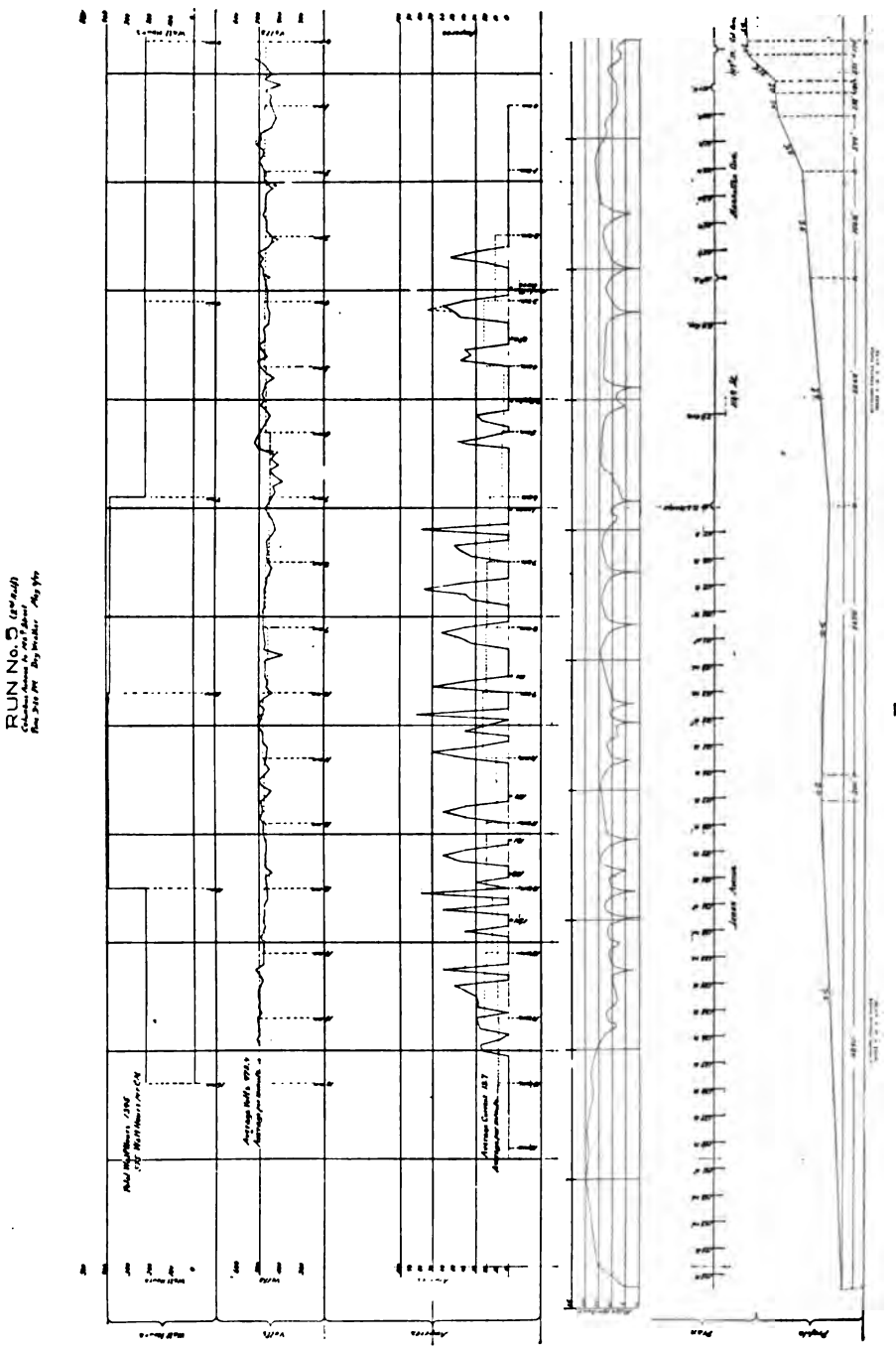

FIG. 7

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In comparing these two sets of results, there is seen to be a decrease in current consumption of 12.6 amperes per car, while the difference in power consumption is 385 watt-hours per car mile The power consumption in running from the station to Columbus Avenue is considerably more than when running in the opposite direction, for the reason that the grades are almost exclusively against the cars while running to Columbus Avenue. This average difference is 192 watt-hours per car mile.

The reproductions of the details of one run (figures 6 and 7,) represent the variation in the potential, current and watt-hours; the changes in grade and the location of the curves are also shown.

The results of the second series of tests were obtained as part of the graduating thesis of F. G. Haldy and G. W. Magalhaes, students in the Electrical Engineering Department of the University.

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ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER, Ph.D.

Potassa or Soda purified by alcohol. Murmann (Zts. Anal. Chem. XXXVI. 379). These reagents often contain Cu, Pb or Fe in minute amounts, which interfere in close determinations of Ni, and some other operations It is recommended to purify the lye by cautious addition of a little H_2S water, and filtering. The excess of H_2S may be removed by adding a little more of the lye, or by addition of H_2O_2 solution.

Percarbonates a new class of oxidizing substances. Constam and V. Haussen (through C. N. LXXVI. 170). When a concentrated solution of K_2CO_3 is electrolyzed and the temperature gradually reduced at 10°C no O is evolved, and the substance afforded is $K_2C_2O_6$ a bluish amorphous powder, apparently $K_2O_2.2CO_2$. The substance is quite hygroscopic, and with water evolves H at ordinary temperatures. In contact with oxidizable matters it manifests oxidizing powers, also with MnO_2 the reaction is:

$$MnO_2 + K_2C_2O_6 = MnCO_3 + K_2CO_3 + O_2.$$

Pure Hydrofluoric acid in small amounts (Allen Analyst. XXI. 87) may be obtained by charging HFl with H_2SO_4 into a large Pt crucible, setting inside of it a smaller crucible, covering both with a round bottomed Pt capsule, and heating gently. The pure HF condensed on the curved bottom of the capsule drips into the smaller crucible. If desired, the mineral to be attacked may be placed in the smaller crucible at the start.

Molybdate reagent. Meillére (J. Pharm. et de Chim [6] III. 61). The ingredients recommended are 200cc. of a 15 per cent. solution of $(NH_4)_2MoO_3$, with 20cc. of diluted H_2SO_4 (1 : 1) and 30cc. HNO_3. This solution keeps indefinitely, and does not deposit MoO_3 even on boiling. In using as precipitant for P_2O_5 it is necessary to start the action by warming. As_2O_5 requires longer warming. In the subsequent Mg precipitation the co-precipitation of MoO_3 may be prevented by adding a little $(NH_4)_3C_6H_5O_7$.

Ammonium Citrate solution. de Roode (J. Amer. Chem. Soc. XVII. 47). The addition of 1g m. of salicylic acid to 5 litres of the solution care fully neutralized for phosphate examinations, etc., is sufficient to preserv the solution perfectly neutral for an unlimited time.

Preservation of titrated permanganate solutions. Meinecke and Schröder (Zts. f. off Chem. III. 5). A layer of vaseline oil protects from evaporation. The action of the permanganate thereon is almost inappreciable after a long time. It is superior to petroleum ether. Vaseline oil is also serviceable in the preservation of standard solutions of KCy, and of $Na_2S_2O_3$ solutions, etc.

Barium Thiosulphate for Standardizing. Mutnianski (Fres. Zts.

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Anal. Chem. XXXVI. 220). The author mentions as his own discovery, the making and use of this salt for iodometry and iodometric alkalimetry, etc. The method is essentially that of Plimpton and Chorley (vide QUARTERLY, XVI. 287) except that he purifies the crystals by a final washing with 95 per cent. alcohol. Shaking the pulverized BaS_2O_3 for 15 minutes with water at 17.°5C. and following affords a hundredth normal solution, by which weighing is made unnecessary.

Pure Oxalic Acid for Standardizing. Riechelmann (Pharm. Centrh. XXXVII. 164) recommends to fill an extraction thimble with fairly pure $H_2C_2O_4.2H_2O$, to insert in a Soxhlet, and extract with ether. A very pure acid is obtained after driving the ether from the flask, which must be dissolved in water, and crystallized out.

Standardizing Alkalimetric Solutions. Worm. (Pharm. Zts. f. Russland XXX. 613) finds that oxalic acid, borax or soda may be used. Borax he regards as the best. $H_2C_2O_4.2H_2O$ requires careful recrystallization from pure water. Na_2CO_3 must be dried thoroughly at 150° C. not ignited.

Standardizing Alkalimetric Solutions. Sorensen (Fres. Zts. Anal. Chem. XXXVI. 639). Pure Na_2CO_3 cannot be readily obtained. Either it contains moisture, or if ignited, a minute amount of NaOH forms. The same is true of $NaHCO_3$. Pure crystallized oxalic acid effloresces a little, even at 20°C. The author proposes the use of pure $Na_2C_2O_4$. The commercial article dissolved in water (1 part is soluble in 32 parts H_2O at 15°, but in about 16 parts of boiling H_2O) neutralized with a faint excess of NaOH, allowed to stand to settle out insoluble impurities, the solution filtered, and evaporated to one-tenth its bulk, then cooled to crystallize out, and recrystallization repeated until it is absolutely free from Na_2SO_4 and NaCl. The more soluble $K_2C_2O_4$ is also eliminated by this process, especially if the crystals are each time washed with cold water. Crystallized in this manner it may decrepitate on ignition, but if the hot aqueous solution of the purified salt is filtered into alcohol, a rather voluminous crop of crystals is obtained which after washing and drying at 125 to 150° will not decrepitate. For use weigh out the desired amount, ignite gently to Na_2CO_3, dissolve and use for standardizing. The dried salt is anhydrous and not hygroscopic.

Alkaline carbonates Qualitative tests, Leys. (J. Pharm. Chim. [6] VI. No. 10). Addition of $MgSO_4$ solution or of a soluble Mg salt to solution of neutral alkaline carbonate gives a white precipatate, but none with alkaline bicarbonate. When neutral carbonate is mixed with bicarbonate or with borax the reaction is different. 32 parts of bicarbonate with up to 68 parts of neutral carbonate give no precipitate; the same is the case with 40 parts of borax and up to 60 of neutral carbonate. $CaSO_4$ with neutral carbonate in very small amounts gives an *immediate* precipitate; with bicarbonate the precipitate forms very slowly, with borax still more slowly, practically none. The reactions are the same in case of mixtures and therefore by this means the presence of neutral carbonate can be detected in presence of bicarbonates or of borax.

Detecting Potassium, Pauly. Pharm. Centrh. (new ser. VIII. 187). The reaction described by Carnot and Campari has been modified thus: To a few drops of $Na_2S_2O_3$ solution add an equal bulk of Bi solution, then

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about 1 cc. of H_2O, and then 10 to 15 cc. of absolute alcohol. If then a separation of $Na_2S_2O_3$ occurs, which gives a turbidity not removable by shaking, add water drop by drop until it becomes clear. Then addition of the solution to be tested drop by drop, affords a fine yellow precipitate of $KBi(S_2O_3)_4$ if K is present. The reaction did not seem to be adapted for quantitative estimations as suggested by Carnot.

Potassium determination, Mayer. (Zts. and Chem. XXXVI. 159.) The Schweitzer-Lungwitz method involves the use of an HCl solution of BaC_2O_4. The modification proposed is as follows: Add water to 20 gms. of the substance (fertilizer, etc.), boil 30 minutes, make up to 500 cc. and filter. To 50 cc. of the solution add normal $BaCl_2$ until it ceases to give a precipitate. Then add an equivalent amount of normal $H_2C_2O_4$ solution, boil 20 minutes, render alkaline with ammonia, make up to 100 cc. and let settle. Then filter and take 50 cc. of the filtrate, evaporate and drive out NH_4 salts by igniting at as low a temperature as possible. Dissolve in water, filter, add 10 cc. $PtCl_4$ solution and evaporate nearly to dryness; after cooling add alcohol, stir for some time and then let stand and filter. Dry at 120° C and weigh.

Analyses of Iron and Steel, C. B. Dudley (J. Am. Chem. Soc. XIX.—) The Ford-Williams method for Mn is satisfactory, when the Mn present is not over 0.75 per cent. Above that figure the results seem to be low, possibly because the chlorate precipitate is not absolutely all MnO_2.

For Si the Drown method, for accurate results, needs constant stirring and prompt filtration, since on standing a little of the SiO_2 reverts to a soluble form.

For S there are still improvements desired which will give accuracy as well as speed. The uncertainty of the evolution methods with some irons and the retention of S in the graphitic residue, as shown by investigations of other chemists, are of serious importance.

Determination of Iron and Alumina in Phosphate. Blattner and Brasseur (Bull. Soc. Chim. [3] XVIII. No. 15). After an examination of several methods, the conclusions are:

1. The acetic acid method should be rejected.
2. Glaser's alcohol method gives fair results if Mn is absent.
3. Lasne's caustic soda method (vide QUARTERLY XVII. 312) is very accurate when all the details described by the author are closely followed.
4. Gruber's method (an abridgement of Lasne's) gives inexact results.
5. Gladding's method (vide QUARTERLY XVIII. 40) in which KOH is used instead of NaOH as in Lasne's contains some modifications, which are liable to become sources of error.
6. The method of direct precipitation affords variable results and practically insuperable difficulties of manipulation.

Separation of Aluminum and Beryllium. Havens (Am. J. Sci. [4] IV., Aug., 1897). A method for the separation of Al_2O_3 and Fe_2O_3 when converted into chlorides, based on the insolubility of $AlCl_3,6H_2O$ in a mixture of HCl and ether when saturated with dry HCl gas has been described (QUARTERLY XVIII. 170). By treating the mixed chlorides of Al and Be in the same manner, the separation from BeO was found to work equally well.

Volumetric for Zinc by Ferrocyanide. De Koninck and Prost (Ch. News LXXVI. 6, 15, 29, 38, 51). Even in presence of an excess of Zn

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the precipitate consists chiefly of $K_2Zn_3Fe_2Cy_{12}$, and not of Zn_2FeCy_6. The first compound is gelatinous, and reacts with UO salts. After a little time, or more rapidly when heated, the precipitate assumes a form in which it no longer gives that reaction. It has, therefore, been found best to add an excess of the standard K_4FeCy_6 solution (20 to 25 per cent. in excess) warming for a short time, and titrating back with a standard $ZnCl_2$ solution.

Nickel in Steels, etc. Ducru (Bull. Soc. Chem. XVII.). Electrolysis in ammoniacal solution in presence of suspended $Fe_2(OH)_6$ causes the co-precipitation of but little Fe. It is likely to be but 0.001 to 0.002 gm., and for many purposes the results are sufficiently close. If more exactness is required, the Ni deposit after weighing may be dissolved in acid, and the Fe estimated (precipitation by NH_4OH) and the amount deducted. 0.25 to 0.30 gm. of the steel is dissolved in aqua regia; then 1cc. H_2SO_4 is added and the solution evaporated to fumes. After cooling the residue is taken up with as little water as possible, 5 to 10 gms. $(NH_4)_2SO_4$ added, and the solution warmed until clear. It is then run into the crucible of a Riche apparatus containing 60 to 70cc. of concentrated ammonia. It is then electrolyzed with a current of 1.5 to 2.5 amperes. About four hours serve for complete deposition. Separation of Si or of C is unnecessary. P, Mn or Cr do not interfere.

H. L. Robinson (Chem. News LXXVI. 265) comments on this paper to the effect that no electrolytic method is likely to supersede the xanthate process for Ni of Andrews and Campbell (J. Lond. Chem. Soc. Abstr., Part II., 1895, p. 421).

Separation of arsenic from antimony. Piloty and Stock (Ber. XXX. 164). Heating a strong HCl solution containing As, while at the same time passing H_2S causes a volatilization of the As. Complete separation from Sb can thus be effected. More complete details are promised.

Electrolytic analysis of Bronze and Brass. Holland (C. Rend. CXXIV. 1451). Treat 5 gms. with 25cc. HNO_3 (SpGr 1.31) and 15cc. conc. H_2SO_4 until decomposed. Dilute then to 350cc. and keep nearly at boiling until the separated SnO_2 has collected at the bottom, leaving the solution clear and bright. Plunge in the Pt cone and spiral without stirring up the sediment and electrolyze for Cu. Evaporate the liquid freed from Cu on the sand bath, heating until but little H_2SO_4 is left. Take up with HCl and water, precipitate the Sn by H_2S, filter and wash with NaCl solution, dissolve in $(NH_4)_2S$, and evaporate to dryness on the water bath. Dissolve the residue by 9 gms. $KClO_3$ and HCl. Evaporate again to dryness on the water bath, and take up the residue with 30cc. HCl and water, filter, dissolve in the solution 30 gms. pure $(NH_4)C_2O_4$ heat to 90°C. and electrolyze with a current of 0.7 amp. The deposition is complete in 12 hours.

For Zn, the filtrate from the SnS_2 is heated to expel H_2S, then evaporated on the sand bath to expel most of the H_2SO_4. Dissolve in water, neutralize with NH_4OH, then add 15 gms. $(NH_4)_3C_6H_5O_7$ and 4cc. of glacial $HC_2H_3O_2$—neutralize with the NH_4OH, then 3cc. glacial $HC_2H_3O_2$ Electrolyzing for about 12 hours, (0.6 ampere) affords the Zn in a firmly adherent deposit. Fe if present will be partly deposited with the Zn. Pb must be determined separately in an HNO_3 solution.

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Copper by the Iodide method. Willenz (Rev. Chim. Analyt. V. No. 8). The method (De Haen's) is said to have been to a considerable extent abandoned by many as inaccurate, although the author states it has been officially adopted in the United States. He finds that with proper care it affords very accurate results. The mode of procedure recommended contains nothing novel.

Silver in Silver plating solutions (Cyanide). Baker (C. N. LXXVI. 167). Precipitation by HCl and weighing gives a precipitate containing $CuCy_2$ and other impurities. Fusing the above precipitate with KNO_3 and Na_2CO, is liable to error from adherence of small globules of Ag to the crucible. The author recommends to precipitate (say) 50cc. of the solution boiling with HNO_3, then to wrap up the precipitate in a small sheet of test lead, and to cupel the button in the usual manner.

A. H. Allen (ib. p. 199) describes his method. It consists in diluting largely 20 to 50cc. of the solution, and precipitating boiling hot by H_2S or $(NH_4)_2S$. The Ag_2S (containing probably CuS, ZnS, etc.), is rinsed from the filter into a flask and treated with Br water. If any S separates a little more Br may be necessary. Boiling water is added and the AgBr is washed, dried, fused and weighed.

For Au in electric gilding solutions (double cyanides) a measured quantity is evaporated in a porcelain crucible until syrupy. A few grms. of pure PbO or Pb_3O_4 is thus added and the evaporation continues to dryness. The crucible is then covered, and heated for a short time to red heat. This affords a lead button containing the Au, which may be cupelled, or else treated with HNO_3. This method is applicable to electro-silvering solutions as well.

Pure Cerium oxide. Wyrowboff and Verneuil (Ch. News LXXV. 292). Ce readily forms a very stable compound $Ce_3O_4.3MO$ in which $M = Ce + La + Di$ in proportions varying to circumstances. If the oxalates of Ce, La and Di mixed together as obtained in this form from samarskite, etc., are dissolved in warm HNO_3, and the solution evaporated to a syrup to remove excess of acid, the mass easily dissolves to a clear solution, unless the mixtures of oxides contains over 50 per cent. of Ce.

After dilution, so that the solution contains 4 per cent. of oxide. and warming, the addition of 5 per cent. of NH_4NO_3 precipitates the whole of the Ce_3O_4 as a basic salt, the compound of the oxides being decomposed. The precipitate, after washing with 5 per cent. NH_4NO_3 is free from La and Di as well as Yt earths. If more than 50 per cent. of Ce is present the oxalates are dissolved in HNO_3, and treated with H_2O_2 and ammonia, boiled to precipitate brown Ce_6O_7, which is dissolved in HNO_3, and the operation from this point is conducted as above.

Separation of Thorium and Cerium acids. Hintz and Weber (Fres. Zts. Anal. Chem. XXXVI. 676). Experiments with the different methods led to the following conclusions: The separation by $Na_2S_2O_3$ is the most satisfactory; it is not absolutely complete, since small amounts of CeO precipitate with ThO_2 and also small amounts of ThO_2 remain dissolved. These errors compensate one another to a considerable extent, and the results are within the limits of experimental error. The $(NH_4)_2C_2O_4$ separation is incomplete in one precipitation; a repetition gives results still too high for CeO in spite of the fact that some Cere-

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mains dissolved in the oxalate. Glaser's method (oxalate with addition of $NH_4C_2H_3O_2$) is open to essentially the same objections.

Thorium. Urban (Bull. Soc. Chim. [3] XV. 347). By forming the acetyl acetonate a very pure thorium salt was obtained. The raw oxalates were treated with $(NH_4)_2C_2O_4$, and instead of precipitating with an acid, the solution was precipitated by NH_4OH. The hydrate, suspended in dilute alcohol, was then treated with acetyl acetone, evaporated to dryness on the water bath, and the acetyl acetonate $Th(C_5H_7O_2)_4$ and taken up with $CHCl_3$. By slow evaporation large crystals are obtained. The salt is but slightly soluble in water, but soluble in most organic solvents. It fuses at 171–172° and sublimes *in vacuo.*

Thorium Determinations. Glaser (Fres. Zts. Anal. Chem. XXXVI. 213). A number of experiments are detailed from which these conclusions are drawn:

1. The assertion that ThO_2 and CeO are precipitated by $(NH_4)_2CO_3$ as by NH_4OH is erroneous. This error was occasioned by the occurrence of the following paragraph in Graham-Otto 4th Ed., 2d part, pp. 902 and 940. "Thoria as well as cerous oxide is easily soluble in excess of ammonium carbonate, like the majority of the earths under consideration, and are precipitated therefrom on boiling."

2. The assertion regarding the relation of thoria to $(NH_4)_2C_2O_4$ should state: "Precipitates cold, soluble in heat, crystallizes out on cooling, in case a large excess of the reagent is avoided. Excess of HCl precipitates the oxalate quantitatively on cooling."

3. The assertion that $Th(C_2O_4)_2$, more accurately, $ThH_2(C_2O_4)_3 + 2H_2O$ held in solution by $(NH_4)C_2H_3O_2$ and $(NH_4)_2C_2O_4$ is partially precipitable by HCl, must be amplified to this, that with a sufficient excess of HCl the precipitation is quantitative.

4. The solubility of $Zr(C_2O_4)_2$ in HCl must be noted.

5. $Ce(CeO_4)_2$ is somewhat soluble in $(NH_4)C_2H_3O_2$.

Halogens in Mineral Waters. Richards (C. N. LXXVI. 293). Vortmann's process is as follows: An aliquot part of the solution containing all three (Cl, Br and I) is boiled with MnO_2 and $HC_2H_3O_2$ which removes all I. Another measured portion is boiled with PbO_2 and $HC_2H_3O_2$ which removes both I and Br. Titrating the original sample with standard $AgNO_3$, also titrating the filtrates each by itself from the above treatments, afford the necessary data for estimating. The author finds this unsatisfactory where one of these halogens largely predominates. The method of Cook he finds to be preferable. This consists first in determining the total halogen equivalent by means of standard $AgNO_3$, then treating 250 or 500cc. of the water for half an hour with $HC_2H_3O_2$ and H_2O_2. This liberates I only, which can be extracted with $CHCl_3$ in a separating funnel, and the $CHCl_3$ solution titrated by standard $Na_2S_2O_3$. The iodine free liquid is then shaken up with a little Cl water and $CHCl_3$, which under these conditions extracts Br. Add a crystal of KI to the $CHCl_3$ and titrate as before by $Na_2S_2O_3$. Cl is then obtainable by difference.

Separation of Chlorine and Bromine. Jaunasch and Kolitz (Zts. Anorg. Chem. XV. 66). The separation of Br by $K_2Mn_2O_8$ in a solution containing $NaC_2H_3O_2$ or acidified with $HC_2H_3O_2$ was found

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to be ineffective (vide QUARTERLY XIII. 384, 385). The presence of sulphates or nitrates, on the other hand, had no disturbing influence.

Distilling off Bromine from a mixture of chloride and bromide. Baubigny and Rivals. (C. Rend 1897, No. 15, October). After adding $CuSO_4$ and $K_2Mn_2O_8$ the Br is most readily and conveniently expelled by passing a current of air through the boiling solution.

Detecting Traces of Bromine. Baubigny and Rivals (C. Rend. CXXV. No. 18). Fluoresceine, properly purified, is treated with pure $HC_2H_3O_2$ (30 to 40 per cent. strength). With this solution strips of filter paper are moistened, and then allowed to dry.

When moistened with the solution to be tested, if Br is present, the least trace will show a rose color. Organic matter should be excluded.

Reduction of SO_2 to H_2S. Donath (Fres. Zts. Anal. Chem. XXXVI. 663) has arranged an apparatus which serves to exhibit this phenomenon, and incidentally it serves for a test for As in certain cases. A flask is fitted with a doubly perforated cork, through one hole passes the tube of a globe stopcock funnel, through the other a tube which passes through a reversed condenser. In the flask is placed a strongly acid (with HCl) solution of $SnCl_2$, and in the globe with stopcock a solution of $NaHSO_3$ or of H_2SO_3. On heating the $SnCl_2$ solution nearly to boiling, and allowing the sulphite solution to drip in slowly, a steady evolution of H_2S is obtained which may be passed into various metallic solutions to demonstrate its presence. The arrangement may be used to test for the presence of As in the tin salt of commerce, or in commercial H_2SO_4 if some of the latter is placed in the flask with the $SnCl_2$ solution.

Titration of sodium thiosulphate with iodic acid. Walker (Am. J. Sci. IV., Sept., 1897). Riegler has asserted that the reaction occurring is: $6Na_2S_3O_3 + 6HIO_3 = 3Na_2S_4O_6 + 5NaIO_3 + NaI + 3\frac{1}{2}O$ and that when an excess of HIO_3 is introduced the reaction is: $5NaI + 6HIO_3 = 5NaIO_3 + 3\frac{1}{2}O + 3I_2$, affording the usual end reaction with starch.

The author finds the conclusions erroneous to a considerable extent due to a variable quality of the HIO_3 ordinarily supplied by dealers, (presence of I_2O_5, etc.); also to the occurrence of complex supplementary reactions which renders the method unsuitable for use.

Estimation of Sulphuric acid. Marboutin (Monit. Sci. [4] XI. per Ch. N. LXXVI. 232). A brief synopsis of different methods which have been proposed is given: 1. Gravimetric with $BaCl_2$. 2. Volumetric.

I. Direct titration with standard $BaCl_2$ (Houzeau). End reaction when there is absence of precipitation.

II. Direct alkalimetric methods. 1. (F. Mohr's.) Adding excess of $BaCO_3$ in presence of a current of CO_2. The alkaline sulphates afford insoluble $BaSO_4$ and alkaline carbonate, which latter is titrated alkalimetrically.

2. Sr method (Mohr and Claussen). After precipitating in presence of alcohol by $SrCl_2$, the $SrSO_4$ is digested with Na_2CO_3 to convert to $SrCO_3$ which is filtered off and titrated with HCl.

3. Pb method managed in a similar manner to the Sr method. Inapplicable in presence of chlorides.

4. (Grossman) $Ba(OH)_2$ is used to precipitate $BaSO_4$, the excess of $Ba(OH)_2$ is separated by CO_2, and the alkali formerly in combination with the SO_3 is titrated.

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5. (Linossier.) After precipitating as $PbSO_4$, this is converted to PbS by H_2S, and the solution titrated with normal NaOH.

III. Indirect alkalimetric methods. 1. (C. Mohr.) After precipitating with a known amount (excess) of $BaCl_2$, the amount of such excess is determined by precipitation with alkaline carbonate and titrating the precipitate. Clemm modifies this by precipitating excess of Ba by adding enough Na_2CO_3 solution to precipitate all the $BaCl_2$ used, and titrating. The excess of Na_2CO_3 remaining measures the amount of SO_3 precipitated.

2. (Bohlig.) Precipitating with excess of $BaCO_3$ in presence of CO_2. The alkali originally combined with SO_3 is then over-neutralized by excess of normal acid and the excess of acid titrated back.

3. Knöfler's method is not intelligibly described.

IV. Precipitation by $BaCl_2$ and determining the excess of that reagent.

1. (Wildenstein) Precipitate with known amount of $BaCl_2$, estimate excess by titration with K_2CrO_4. End reaction is the yellow color of the solution.

2. (Precht) uses K_2CrO_4 and estimates the excess by use of a titrated ferrous solution.

3. The principle is the same also for Pellet's and Quanten's methods.

4. (Mohr and Classen) titrate the excess of K_2CrO_4 by use of KI and standard $Na_2S_2O_3$.

5. (Windisch) excess of K_2CrO_4 titrated by KI and standard As_2O_3 solution.

V. Precipitation as $PbSO_4$. 1. (Levol) titration with standard solution of Pb. End reaction shown by the yellow color of PbI_2, a little KI being added as an indicator.

2. (Guyard) determines the amount of the solution to be tested which is required to decolorize a solution containing a known amount of Pb $(C_2H_3O_2)_2$ to which a drop of KI solution has been added. The reverse of Levol's method.

Other methods have been brought up in which the excess of chromate (after precipitation with Pb salt and then with K_2CrO_4) is determined by use of Ag salts. None of the Pb methods are applicable in presence of chlorides.

The author precipitates the SO_3 with excess of standard $BaCl_2$. This excess is in turn precipitated with excess of standard K_2CrO_4, the excess is reduced by use of standard As_2O_3 solution and excess of As_2O_3 titrated with standard I solution.

Colorimetric for Disulphuric Acid. Barral (J. Pharm. Chem. [6] VI. No. 3). Parabichloride of hexachloridized benzene, $C_6Cl_6.Cl_2$ (1–4) gives a fine reddish violet coloration with H_2SO_4 containing $H_2S_2O_7$. The reaction does not occur with dry SO_3, and the coloration disappears as soon as enough H_2O has entered into combination to form H_2SO_4.

A known amount of the Nordhausen acid to be tested is shaken in a flask with a little powdered C_6Cl_6. Then accurately titrated H_2SO_4 (66° acid with one-tenth its weight of water) is run in cautiously from a burette drop by drop until the color is destroyed. With yellow or brown Nordhausen, the exact point of disappearance of the color is often difficult to observe.

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Determination of Boric Acid as potassium fluoboride. Thaddeeff (Fres. Zts. Anal. Chem. XXXVI. 568). After an extended research the author gives the preference to the determination as KBF_4 (a modified Berzelius-Stromeyer method). To the solution, containing the B as alkaline borate is added approximately 2 gms. KOH, the amount of water being kept small. To this solution in a platinum dish is added an excess of c.p., HF. and the whole is evaporated on a water bath. Toward the end the crust which forms is broken up by a stout platinum wire. The dish is left on the water bath until only a slight odor of HF is perceptible. (This small excess is rather advantageous than otherwise.) After cooling add 50cc. of a clear $KC_2H_3O_2$ solution (Sp. Gr. 1.14). Allow to stand for one to two hours at the ordinary temperature, with occasional stirring, breaking up the lumps to allow the solution to penetrate completely. Then add 100cc. of alcohol (Sp. Gr. 0.805), stir well, and allow to stand 12 to 14 hours. Prepare a weighed filter by wetting down with alcohol, and thorough drying (followed by weighing). Filter through a ribbed glass funnel. Rinse the precipitate onto the filter with alcohol. Tapping the filter is of assistance in shaking the precipitate soldidly down into the point of the filter. About 60 to 70cc. of alcohol can be made to suffice for washing. Dry for three hours at 100 to 110° and weigh. Test the precipitate for contamination with KF.HF. by boiling with water, and adding $CaCl_2$.

Phosphoric acid (citrate process): Lasne (Bull. Soc. Chim. XVII.) The results of some experiments are detailed. The conclusions are: 1. The estimation of P_2O_5 as $Mg_2P_2O_7$, after preliminary separation of SiO_2 gives trustworthy results.

2. Rapid precipitations give high results due to partial formation of $Mg_3(PO_4)_2$, which is only transformed into $MgNH_4PO_4$ after 16 hours' contact with sufficiently concentrated $(NH_4)_3C_6H_5O_7$ (10 gms. $H_3C_6H_5O_7$ in 150cc. of solution).

3. Nevertheless the excess is not sufficient to condemn the rapid methods, which can be used commercially, if due notice is given.

4. Conversion of $Mg_3(PO_4)_2$ into $MgNH_4PO_4$ is slow in the presence of NH_4Cl alone. Citric acid should always be added.

5. Precipitation of Mg in presence of an excess of $(NH_4)_3PO_4$ affords simultaneously with $MgNH_4PO_4$ a phosphate poorer in Mg, also poorer the greater the excess of P_2O_5 present. Hence the estimation of Mg by this method is always inaccurate.

Volumetric for phosphoric and arsenic acids. Christensen (Fres. Zts. Anal. Chem. XXXVI. 81). The stronger mineral acids as H_2SO_4—by taking the base from a mixture of iodide and iodate, allow an interaction between the HI and HIO_3 which liberates iodine, and the degree of acidity may be determined by use of standard $Na_2S_2O_3$, *e. g.*

$$KIO_3 + 5KI + 3H_2SO_4 = 3K_2SO_4 + I_6 + 3H_2O.$$

(vide QUARTERLY XII. 60.) If, however, the solution contains a phosphate to which an excess of H_2SO_4 has been added, so as to afford H_3PO_4, the reaction affords MH_2PO_4 thus:

$$KIrO_3 + 5KI + 6H_3PO_4 = 6KH_2PO_4 + I_6 + 3H_2O.$$

By comparison of the amount of I set free by a known amount of

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H_2SO_4 with the amount set free by using the same amount of H_2SO_4 after it has been adeed to a solution of phosphate, the amount of phosphate present can be determined. The author finds that sharper and more accurate results can be obtained by using a mixture of $KBrO_3$ and KI, 2.5 gms. of the former to 2 gms. of the latter. The reactions are:

$$KBrO_3 + 6KI + 3H_2SO_4 = 3K_2SO_4 + I_6 + KI + 3H_2O$$

and $$KBrO_3 + 6KI + 6H_3PO_4 = 6KH_2PO_4 + I_6 + KBr + 3H_2O.$$

Heating for half an hour in a tight stoppered flask at 40 to 50° after adding the standard H_2SO_4, and then cooling before opening to titrate, affords the best results.

From $Ca_3(PO_4)_2$ the H_3PO_4 is separated as the Ag compound, which is then boiled with NaCl. In most other cases separation as $MgNH_4PO_4$, which is washed with alcohol, is the most convenient.

Carbon in Ferro Chrome. Saniter (Chem. News, LXXV. 287). 0.5 gm. of the finely pulverized material is mixed with 4.5 gms. CuO and 0.5 gm. PbO (prepared by fusing red lead) and the mixture placed in a porcelain boat. The combustion is then conducted in the ordinary manner. 20 minutes will suffice for complete combustion of the C. Porcelain tube. Bright red heat.

Brearly prefers PbO_2 instead of PbO (ib., p. 311).

Nitrous acid in waters, etc., Riegler (Fres. Zts. Anal. Chem. XXXVI. 30b). To 100 cc. of the water in a flask add a small penknife point full of naphthionic acid (about 0.05 gm.), shake up well and then add 30 drops of conc. ammonia solution. The rose tint developed is compared with that obtained with a standard solution made up by use of pure $AgNO_2$ and NaCl, and suitably diluted. Dissolve 0.406 gm. $AgNO_2$ in hot water, add a slight excess of NaCl, cool, filter, dilute to 1 litre, of the filtrate dilute 100 cc. to 1 litre of which 100 cc. (= 0.001 gm. N_2O_3) is used for the comparison, after adding a little HCl.

Reagent for nitrous acid, Riegler. (Zts. Anal. Chem. XXXVI. 377). A reagent much more sensitive than the naphthionic acid described already by the same author (vide QUARTERLY XVIII. 443) is made by adding 2 gms. pure sodium naphthionate and 1 gm. Beta naphthol (both puriss.) to 200 cc. of water, shaking and filtering. To test a water, etc., take 10 cc. thereof, add 10 drops of the reagent and 2 drops conc. Hcl, mix well by shaking and then allow about 20 drops of ammonia to flow down the side of the test tube. If HNO_2 is present a reddish ring appears at the junction of the two liquids, which by shaking is spread through the solution with an intensity proportional to the amount of HNO_2 present. One part in 100 million can thus be detected.

Conditions of Elements in Steels, Carnot and Goutal (C. Rend CXXV. 221). Mn, Ni, Cu and Ti appear to be simply dissolved in the steels; a portion of the Mn may be in the state of sulphide or silicide. W and Mo. are in a state of combination with the iron as Fe_3W. and Fe_3Mo_2.

Possible New Element. Boucher (Chem. News, LXXVI. 99) describes some of the properties of what seems to be a new element obtained from cast iron and blast furnace boiler dust.

To obtain it, cast iron is dissolved in H_2SO_4, the solution precipitated by H_2S, the sulphides dissolved in HCl and $KClO_3$, the solution evapo-

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rated, As precipitated out by $MgCl_2$, etc. In the ammoniacal solution, any Cu remaining is separated by H_2S. On acidifying the filtrate, the metal separates as a dark brown sulphide possibly contaminated by Sb. Repeated boiling with dilute HCl will remove the Sb, and the residual sulphide is dissolved in KOH, and H_2S passed through, the operation being repeated until the KOH solution of the sulphide gives no precipitate with H_2S. The sulphide may be dissolved in HNO_3 and further purified as may be necessary. Cautious ignition of the sulphide affords a pale yellow oxide vaporizing at full red heat. Fusion with KCy affords the metal as a black powder, which is only slightly soluble in HCl or H_2SO_4, but soluble in HNO_3 or aqua regia. In a borax bead the oxide gives OFl colorless, RFl pink bead; Na_2CO_3 colorless mass completely soluble in water. The chloride solution with caustic alkalies gives a light blue coloration but no precipitate, with Zn or Fe black metal is precipitated (some metal escapes in combination with H and gives a spot on cold porcelain); with $Na_2S_2O_3$ violet coloration affording finally the brown sulphide. Addition of H_2SO_4 and evaporating to fumes, the solution on cooling eventually shows a blue color which is destroyed by dilution, K_4FeCy_6 gives a dark brown flocculent precipitate only in neutral solutions. Other reagents, as $ZnCl_2$, $FeSO_4$, alkaline earth carbonates, KCy, K_2CrO_4, Na_2HPO_4, etc., show no reaction with its solutions. Ruddock (ib., p. 118) appears to have encountered the same substance in a small amount of iron substituted to him for examination. A suggestion that the properties of the element seem to point to Mo (ib., p. 171) is met by the author with the reply (ib., p. 182) that it fails to give the yellow precipitate with phosphate, although in many other respects the reactions are similar to those of Mo.

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF CHEMISTRY.

During the past year so many changes have taken place both in the staff and the courses of instruction, as well as in the equipment of this department, that it is only proper to give a brief description of them to the QUARTERLY.

CHANGES IN THE STAFF.

All our readers have probably heard, by this time, of the sad death of Professor C. E. Colby, who for many years was in charge of the Organic Laboratory. He had been suffering all his life from a weak physique, and it was only his indomitable courage and his will power which enabled him to carry on his work as long as he did. An unusually talented as well as an unusually gentle and lovable man, his absence will be long felt by his many friends and admirers in and out of the school.

His position in charge of the work in Organic Chemistry has been taken by Mr. Bogert (College '90 School of Mines '94), who ever since graduation has been Professor Colby's assistant, and who, in

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addition to his responsible and laborious work in instruction, has during the last year or two been conducting and of late publishing some interesting investigations on the relations of the composition of organic bodies to their physiological action. Mr. Bogert is assisted by Dr. Harper, a graduate of Cincinnati University and a Ph.D., of Berlin, who has lately returned from Germany after a long course in Organic Chemistry under Professors Fischer and Gabriel.

Another addition to our staff from outside our own ranks was made last spring when Dr. Livingston R. Morgan was appointed to the charge of the new laboratory of Physical Chemistry. Dr. Morgan graduated at Rutgers in '92 and then studied for three years in Leipzig under Professor Ostwald, returning to this country with the degree of Ph.D. He has published some valuable works on his special subject, and is organizing interesting laboratory courses in pure Theoretical Chemistry.

In the Analytical Departentment Professor Ricketts, with Drs. Wells and Miller, instructors, and four assistants, all School of Mines graduates, is rapidly developing his courses to correspond with the improved laboratory facilities. Dr. Vulte, with two assistants, is now in charge of the first-year laboratories at the Medical Department, giving the budding doctors the same course in general chemistry that is given to the college men by Mr. Van Gelder, under the supervision of Professor Pellew. The latter gives the lectures on chemistry to the medical students, formerly given by Dr. Chandler, and also, with the assistance of Mr. S. A. Tucker, '95, has charge of the new Laboratory of Industrial Chemistry.

CHANGES IN THE COURSE..

More deep reaching, however, than these changes in the staff, numerous though they may be, are the fundamental changes in the courses of instruction. The student in the School of Chemistry in his third year has his choice of three options, the analytical, organic or industrial, and the work of the last two years is based upon his choice. The analytical option, attracting this year many students, includes new courses of lectures and laboratory work, and is being made as practical as possible, and will include the short commercial methods used in manufacturing and metallurgical works. A new system of instruction has been adopted both for this course and the second-year course for the electrical engineers. The lectures are typewritten and delivered to students, who then recite on the subject, and have the notes for use in the laboratory. The "Organic" students spend most of their time working in organic or theoretical chemistry, and, in the new laboratories, have excellent facilities for not only doing routine work, but also, as is being recognized by several post-graduates, of pursuing some interesting and important original investigations under Mr. Bogert and Dr. Morgan. Those taking the third option work in yet another and not the least interesting field; they are trying to get a training which will start them in the broad and ever expanding field of manufacturing and industrial chemistry.

The latter course, as an entire innovation in the department, introduced this year by the special efforts of Professor Chandler, may, perhaps, deserve special attention. All the chemical students in the first term of the third year spend three afternoons a week in the Industrial Laboratory, preparing various inorganic compounds, as far as possible on commercial

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methods and on a fairly large scale. A fine equipment has been provided, thanks to a friend of Dr. Tucker, of steam evaporators, filter presses, autoclaves, centrifugals and the like, and great pains are taken to ensure the absolute purity as well as the quantity of the output.

Besides this the "Industrials" take two terms, the other students one term, of work in special branches of chemical technology. This spring term the classes will be engaged on textile fabrics, dyeing and calico printing, and, later, on fermentation and distillation. Next year it is hoped to pursue courses in water and sewage filtration, electro-chemistry, and in petroleum and sugar manufacture, as time and equipment may permit.

The possibilities of such a course are enormous, but only to be developed by slow degreee; and so for the first two or three years the effort will be made to cover one or two branches, each term, thoroughly, rather than to dabble with several. Along with the laboratory instruction will run, as far as possible, a course of instruction in factories. A summer school in chemistry was started last June by Messrs. Pellew and Tucker, who for two weeks conducted the students through chemical factories in and near New York; and arrangements have been made this spring so that students can see plenty of factory practice in their special line of work, as well as join excursions with the students in metallurgy and mechanical engineering. It is only proper to refer here to the great kindness and assistance extended to instructors in this laboratory by numerous manufacturers, both graduates of the school and outsiders.

Two other innovations in the department should be mentioned, both of them the natural consequences of the new equipments. The first is the organization of a chemical library, a handsome, well-lighted room on the ground floor of Havemeyer Hall, in which are kept the more recent chemical books belonging to the department and to the University library, the bound journals, and also, thanks to the kindness of Mr. Baker, the current chemical periodicals. Some generous friends have subscribed enough money to support a competent attendant, and it is hoped that the easy access to books and journals will be appreciated both by our students and our graduates.

The Chemical library is open every day from 12:30 to 8:30 p. m., and, on request, is kept open till 10 p. m. It is also kept open on Monday, Tuesday and Friday mornings from 10 o'clock on.

The second change, which has just been decided upon, relates to the first-year work in Chemistry for all the students working in the new laboratories. It is proposed to divide the first-year work in two and to place the Qualitative Analysis in the second term, devoting the first term to as broad and as thorough a course as possible in experimental General Chemistry. The latter would probably be the same as that now taught to the College men and to the first-year men at the Medical Department. It is believed that this change, when accomplished, will result in a much broader foundation for the work of the following years.

THE NEW LABORATORIES.

But these many developments, which will tend so much, we hope, to the broadening and strengthening of our Chemical Department, would have been impossible but for the generosity of the members of a great

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family in building such a noble memorial to the memory of the late Frederick Christian Havemeyer.

It would be wearisome to describe in detail the various beauties of a great building like Havemeyer Hall. The large, two story basement is at present largely occupied by the Department of Metallurgy, but contains as well the Assay Laboratory, excellently equipped with gas and coal furnaces, and all the latest conveniences. On the first floor is situated the great chemical lecture room, the largest and handsomest in the University, with 316 seats, and a great lecture table fitted with high and low pressure electricity, gas, pressure, vacuum, water and steam. All around the rear of the room, in a great semicircle, under the raised seats, is a great, well-lighted store-room for the lecture preparations, communicating at one side with Professor Chandler's private laboratories and on the other side with Dr. Laudy's rooms and through them to the large Chemical Museum, occupying the whole East Wing. The front of this floor is occupied by two smaller lecture rooms, the Dean's room, and, last but not least in importance, the Chemical Library.

On the second floor are situated, in each wing, the large Industrial and Organic Laboratories, respectively. The former is a large open room, connecting with smaller rooms for special purposes at each end, and is being steadily and carefully equipped with various forms of power and apparatus suitable to work.

The Organic Laboratory is a beautiful spacious room, with forty large desks, each fitted with water, gas, pressure, exhaust and electricity, and with several side rooms for balances, glass blowing, combustions and the like. The Laboratory of Physical Chemistry, with a recitation room and rooms for the instructors, complete the floor.

On the third floor we find the two large laboratories of Quantitative and Qualitative Analysis, along with many rooms for special analytical work, for instructors, for recitation and for apparatus. The Quantitative Laboratory contains 72 desks, each equipped with water, gas, pressure, exhaust and electricity, and contains a large and well lighted balance room, centrally located. It is supplemented by special rooms for water, gas, electrolytical and volumetric analysis. Attached to Professor Rickett's office is a room equipped for miscroscopic work and also as a library, where a small but well selected assortment of books on analytical work are always at the disposal of the students. The other wing is occupied by the Qualitative Laboratory, used also for the General Chemistry course of the College students. The desks, 96 in all, each provided with two sets of drawers and cupboards, are very convenient, and are each provided with a deep rectangular sink, which can be used as a pneumatic trough. It is hardly necessary to say that the ancient, paper labelled reagent bottles, so familiar to past generations, have been replaced by handsome porcelain labelled bottles, imported from Germany.

The fourth floor, this year has been loaned to our friends the Architects, who have such comfortable, well lit, well arranged quarters there that it will be difficult, we fear, ever to induce them to move. This remark will probably seem inhospitable, and yet it is a fact that, in spite of our superb new quarters, we are even now crowded in the Qualitative Laboratory, and shall hardly consider our equipment complete until we have a large General Chemistry Laboratory, capable of accomodating the students in that subject from the College, School of Applied Science and Medical

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Department combined. Indeed, if the department develops as we hope it will, it will not be long before some of the other laboratories, notably the Industrial Laboratory, will be demanding more room.

But we are talking now of the present, not of the future, and we hope that we have shown our readers that the Chemical Department now has a superb equipment, and is utilizing it.

BOOK REVIEWS.

Applied Mechanics. A Treatise for the use of Students who have time to work Experimental, Numerical and Graphical Exercises illustrating the Subject. By JOHN PERRY, M.E., D.Sc., F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science, South Kensington, etc. D. Van Nostrand Co., New York. 1898. 8vo., cloth, 650 pages with 371 illustrations. $2.50.

A very brief examination of the book will show that its author has devoted many years to the study of mechanics in its applications to engineering. It is a compilation of the results of a teacher's work in classroom and laboratory and exceedingly characteristic in its treatment of the subject.

In the introduction Professor Perry states that "the Student of Applied Mechanics is supposed to have some acquaintance with mechanical principles" before following the course of iustruction indicated by the volume. Very little space, if any, is given to mathematical deductions of mechanical principles. The working equations in the main are stated and directly applied, and it is evident that the student of the work is expected to be well informed in the various branches of analytical mechanics.

Too much importance can never be ascribed to a knowledge of analytical mechanics and the use of the calculus and other higher branches of mathematics in dealing with the various problems that appeal to the engineer, but Professor Perry clearly and carefully states that such knowledge of itself will not suffice and that the teacher must be careful not to subordinate a portion of the subject to that branch which particularly appeals to him. A knowledge of pure theory is very essential, but equally important is experience in applying pure theory to practical examples. And in this connection the author introduces his method with the following remark: "The most important lesson for a beginner, however he may have studied mathematics and mechanics, and however able he may be as a mathematician, is this—that he must not go on merely assuming that he knows how to do things; he must know things by actual trial and not by hearsay. He must actually calculate certain numerical results; he must actually illustrate principles with laboratory apparatus, and, if there is a school workshop, he must get to know the properties of materials by chipping and filing and paring and planing and turning." Again he says: "Students cannot spend too much time in multiplying, factoring and simplifying algebraical and trigonometical expressions."

The first chapter concerns the rules of computation most commonly

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used in theoretical and practical calculations and will be very suggestive to the student. Each rule is explained by examples. In fact, there is hardly a page in the volume which does not present at least one problem. The book is a treatise on arithmetical computations alone.

In the following chapters, of which there are 29, are described numerous experiments, models, machines and laboratory equipments intended to explain or illustrate theoretical principles. Each chapter deals with a particular branch of the subject; for example, Chap. III. treats of Work and Energy, Chap. IV. of Friction, Chap. V. of Efficiency, Chap. XVI. of Bending, Chap. XXII. of Metal Arches, Chap. XXIII. of the Force of a Blow, Chap. XXIV. of Fluids in Motion, Chap. XXVIII. of Springs, etc. There is no necessary connection between these chapters. Each contains such illustrative problems as the author thinks will help the student. For calculation he draws continually from the mechanical field of engineering, and pays particular attention to steam engines, pumps, and purely mechanical contrivances.

While the volume contains many quaint passages, and is not always clear in its definitions, it will nevertheless be a valuable addition to the applied branch of mechanical literature. It is a storehouse of mechanical facts and problems and should prove itself an aid to the student who cares to use computation in applying theoretical analysis to the solution of practical problems.

C. D., Jr.

High Masonry Dams. By E. Sherman Gould, M. Am. Soc. C. E., Consulting Engineer for Water Works. D. Van Nostrand Co., New York. 1897. 16mo., boards, 88 pages. $0.50.

This little volume replaces the original No. 22 of the Van Nostrand's Science Series and deals, as its title shows, with the same subject.

In the first chapter the author considers the static stresses which act above any horizontal joint and shows that for a rectangular vertical section and moderate heights the base should be from ½ to ¾ the height. Continuing, he finds that an equivalent trapezoidal section gives practically the same stability against overturning with a large gain in economy of material. In the analysis it is also shown that with proper precautions taken in the design a dam which is strong enough to withstand overturning about the outer toe will also be strong enough to resist sliding along joints.

Chapter 2 shows that for dams above about 80 feet high overturning no longer decides the length of joint, but that possible crushing of the material due to its own weight becomes the important factor in the analysis. These principles are stated mainly in narrative without the use of mathematics, and by the aid of various ideal pyramids the conclusion is reached that when certain moderate heights are exceeded enormous quantities of material become necessary, indicating a practical limit to the height to which the structure can be raised.

In chapter 3 is considered the probable law of distribution of unit stress in a rigid masonry joint, and a formula expressing such a law is given by the author and compared with the well known French ones. The chapter closes with a discussion of working values.

In chapter 4 designs for the vertical section of a high dam are made from assumed data, but the treatment presupposes a considerable knowl-

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edge of the laws governing typical sections, so that while the essay may be suggestive to an engineer it can be of little value to the student.

Chapter 5 considers the actual construction apart from the mathematical design. Such topics as the selection of the plan, the management of the flow of the stream during construction, the proper treatment of the excavation and its necessary pumping plant, the selection of the class of masonry to be used, etc., are briefly discussed.

In the final chapter the important accessories of dams are mentioned.

The book cannot be considered nor is it intended as a treatise on the subject, yet in its limited number of pages the main features of the design and construction and the general principles and facts affecting all of the structures of this class are clearly and carefully given.

C. D., JR.

The Induction Coil in Practical Work. By LOUIS WRIGHT. The Macmillan Company. Pp. 172 with 76 illustrations. Price, $1.25.

Under this title the author presents many practical points and gives clear directions to be followed in performing many experiments that require the use of an induction coil. He also takes the opportunity to present in a clear, concise form the work done by Crookes, Hittorf, Puluj and others with vacuum tubes, closing with a treatment of Röntgen Rays.

The discussion of the simple phenomena of charge, current and its effects, magnetism and magneto-electric induction serves not only as an introduction, but as a means for presenting the principles underlying the action of the induction coil. A detailed description as to the construction and action of the different parts, consideration as to the coil to be selected for particular kind of work, points as to the care and preservation of the same, together with detailed directions as to manipulation, form the topics discussed in the second and third chapters.

The middle portion of the book is a condensed but very clear description of the phenomena that have been observed in regard to the discharge of a coil previous to 1895. Among the subjects touched upon one finds "the discharge in air," "discharge in partial vacua," "discharge in high vacua" and "spectrum of discharge." Presented in this manner the changes in the character of the discharge with the vacuum are made strikingly apparent to the reader.

The closing chapter on Röntgen Rays covers forty odd pages, beginning with a short history of Lenard's and Röntgen's discoveries, followed by discussions on the choice and management of tubes, with specific directions as to methods of manipulation in order to obtain the best results in radiography.

The book is not only valuable as a practical guide, but also as a reference in vacuum-tube work, saving the student the necessity of looking up the original papers on this fascinating and important subject.

W. H. F.

Manual of Hydraulic Mining for the Use of the Practical Miner. By T. F. VAN WAGENEN, E. M. Second edition revised. D. Van Nostrand Co. 1897. Pp. 92, 18mo. Price, $1.00.

In this little book, first published some years ago, the author addresses himself to those who are altogether lacking in technical education, but

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who, at the same time, have a general practical knowledge of the subject. For this reason, a relatively large portion of the book is given to some of the primary arithmetical operations, together with definitions and a few of the elementary principles of hydraulics. In the succeeding chapters the construction of water ways—ditch flume, and piping—is touched upon briefly, followed by a simple exposition of the problems likely to arise in carrying out the work, such as relate to grades, cross-sectional areas, head, velocity of flow and volume of discharge. The last chapter treats of sluices, riffles and the saving of the gold. One of the best things in the book is the demonstration of problems relating to the "hydraulic grade line."

The author conveys a large amount of information in this brief outline, but the suggestion is inevitable that condensation has been carried to an extreme point. Many important details, such as those relating to "undercurrents," bed-rock sluices and branch sluices, are altogether neglected.

R. P.

A Description of Minerals of Commercial Value. By D. M. BARRINGER, AM., LL.B. John Wiley & Sons. 1897. 168 pages. $2.50.

The minerals described in this book are tabulated according to the economically important element in their composition and contain in parallel columns a statement of the principal characters and uses.

The work will be found convenient in size and arrangement by prospectors and others interested in minerals. It is not planned to be used in systematic determination, but is essentially descriptive.

A. J. M.

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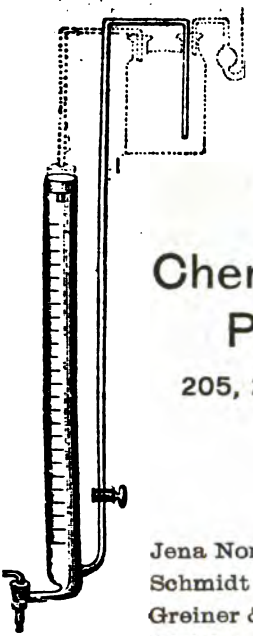

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CONTENTS:

Management of Blast Furnaces—Transition from "Rule of Thumb" to Application of Scientific Methods. By E. S. Cook 227
The Minor Planets. By John K. Rees..... 248
An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D..... 260
Tests of Full-Sized Cast Iron Columns. By William H. Burr..... 283
The School of Architecture in its New Quarters. By Professor William R. Ware..... 289
The Chronology of the Mississippi System. By James L. Greenleaf 296
A Sliding Stadia Rod. By Gilbert Thompson..... 302
Abstracts in Metallurgy. By Joseph Struthers, Ph.D..... 305
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph.D. 315
Alumni and University News..... 327
Book Reviews..... 328

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THE

SCHOOL OF MINES QUARTERLY.

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MANAGEMENT OF BLAST FURNACES—TRANSITION FROM "RULE OF THUMB" TO APPLICATION OF SCIENTIFIC METHODS.*

BY E. S. COOK, Pottstown, Pa.

INTRODUCTION.

In discussing this subject the object sought may be best attained by giving an account of my own experiences rather than by treating it in a general way.

My first intimate acquaintance with the blast furnace dates from 1871. At that time it was generally believed that no one was competent to manage the practical end of blast furnace work unless he was "born in a tuyere arch." This expression was meant to imply that the mysteries could only be solved and handled by a man starting as a laborer and working up through the various positions pertaining to the stock-house and cast-house—first helper, keeper, and finally founder—involving an experience of five to ten years or more. The founders were men separated by the process of natural selection from their fellow workmen, possessing more than ordinary natural intelligence and good judgment, quick to meet emergencies, of some mechanical skill and close observers of blast furnace phenomena.

The Managing Partner, or Business Manager, as a rule, possessed little or no practical knowledge of making iron. He bought the material, ofttimes at the dictation of the founder, in whom resided the power to condemn or approve.

* A lecture delivered to third year students taking the course of metallurgy in the Schools of Mines and Chemistry, Columbia University.

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The total product of the active furnaces during the year 1872 was about 2,500,000 tons. The product for 1897 nearly reached 10,000,000 (9,652,680 tons), while the total capacity of all the furnaces now erected is estimated at 14,000,000 to 15,000,000 tons.

This wonderful increase is due, in great part, to the application of scientific methods to the management of blast furnaces, the New Method replacing the "rule of thumb" practice, or the system of guess work in which the furnace itself was the laboratory.

The discovery of Sir Henry Bessemer, and the introduction of the Bessemer steel rail, has revolutionized the traffic and transportation of the commercial and industrial world. Pig iron, however, is the basis of the steel manufacture. With pig iron costing from $25 to $30 per ton to make, it is evident that steel rails could not have been made and sold for less than one cent per pound. Better management of blast furnaces reduced the cost of manufacture, lower priced pig metal made cheaper rails possible, cheaper rails reduced transportation charges. These causes acted and reacted upon one another so that the world is now furnished with pig iron and steel in their various forms, at lower rates than were even conceived as being within the range of possibility.

This in turn has led to an increased use. Notwithstanding, however, the vast consumption, productive capacity is in excess of current demands.

A few enthusiastic young men happened, by chance or otherwise, to obtain control of the practical working of several furnaces.

They formed the nucleus of the new order of blast furnace management and demonstrated that energy, close application to details, and untiring industry, together with a broader intelligence, capable of applying the teachings of chemistry, could profitably replace the old order, where guess work formed the foundation, assisted by shrewd observation and long experience.

The new method reduced the risks, but the improved results were only obtained by hard work and many disappointments and trials. We had to learn by bitter experiences how to properly apply the analyses furnished by the laboratory, the manager, in most cases, being his own chemist.

Notwithstanding intense commercial competition, it is worth noting that the more intelligent and liberal minded managers exchange thoughts and experiences with the utmost freedom, so that these friendly meetings and friendly competitions to excel

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were largely instrumental in adding to the efficiency of each individual manager. Previous to 1873 metallurgical literature was sadly deficient so far as it related to the blast furnace. It was suggestive rather than instructive, and valuable to this extent. With the growth of the American Institute of Mining Engineers and the British Iron and Steel Institute, and following the Centennial Exhibition in 1876, the literature of the blast furnace rapidly increased. It now forms a valuable aid to all interested in the development of the business.

Intelligent management, with its improved results, brought with it a demand for better appliances, better equipped furnaces, different constructions, etc., so that the blast furnace engineer, practically unknown before, now became a feature. He gathered up the experiences of the various managers, became a medium of exchange, formulated, combined, suggested and devised many useful appliances, so that he assumed a position of no little importance.

It is rather a curious incident, however, that men trained as mechanical engineers did not become the most successful managers; a different bent or training of mind seemed essential.

The Blast Furnace.

I will not refer to the theory of the chemistry of blast furnace operations other than to remark that if it were a melting operation only, such as takes place in a cupola, it would be comparatively simple.

It becomes complex because of the chemical reactions, upon which depend the removal of the oxygen from the ores, and the mechanical difficulties that beset the descent of the materials, and the ascent of the gases of combustion through the column of descending solids.

It was not long after I became the manager of a furnace that I discovered it was one thing to criticise the actions of the founder after the event and quite another thing to have the sole responsibility and to foresee the result of a certain course of action.

Hindsight is the gift of the many, but correct foresight in blast furnace work, as in any other department of activity, is confined to the few. While great progress has been made by the present generation of blast furnace managers, there yet remains much to be accomplished. Not unfrequently I am forced to confess how little I really know about the operations of a furnace and what little control I have over the process. In fact, after a practical ex-

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perience of twenty-three years, I realize more than ever before how much there is to be learned in order to perfectly control the operations of a blast furnace. Sometimes the furnace seemingly runs itself, moving along with the regularity of clockwork, which becomes almost monotonous, and then is followed by irregularities more or less serious, causing the manager a nervous strain and physical exhaustion, with a feeling of mortification at his apparent helplessness and of disgust that he knows so little.

A furnace seems to have an individuality.

Two furnaces, side by side, fed with the same material and under the same management, may work entirely differently and demand different treatment to obtain good results, showing, in fact, the unaccountable differences that frequently characterize different members of the same family. There is a close resemblance between the profession of a furnace manager and that of a physician.

A furnace is always spoken of as possessing sex. Objects to which we become attached are idealized and we fondly refer to them as if they were of the same sex as the mothers, wives or girls we love.

Indications of the internal hidden working are the volume and pressure of blasts, the tuyeres, the slag, the escaping gases, the rate and manner of the settling of the stock on top, and the grade, composition and tonnage of iron produced. A cold top and a hot bottom are just as essential to a healthy furnace as a cool head and warm feet to the individual.

Fluxing.

Chemistry has simplified and rendered comparatively easy the fluxing of the earthy constituents of the various ores employed, plus the ashes of the fuel. In previous years this was the chief cause of trouble. Guesses were made as to the proper flux to be employed. Mistakes were followed by serious irregularities, such as high fuel consumption, worthless iron, and frequent scaffolds and occasionally the chilling of the furnace, involving heavy losses.

Fortunately there is considerable range, so far as safety to the furnace is concerned, in the composition of slag.

When a choice of material is possible the skill of the manager is displayed in making a combination of ores that will give the results desired with the least expenditure of fuel.

The most fusible slags theoretically are not the most economical practically, and in fact cannot be successfully employed in anthracite and coke furnaces.

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Silicious slags, easily fusible, attack the brick work of the lining and of the bosh. They become pasty above the line of fusion, frequently inducing scaffolds or arches, to say nothing of the evil effects upon the quality and grade of iron caused by the absorption of sulphur.

In proportioning the flux, care must be taken to provide for the removal of the sulphur of the fuel, as well as the sulphur contained in the ores. It is also conditioned upon the composition of the iron to be made. If the volume of slag is large per ton of iron a somewhat silicious slag can be depended upon to remove the sulphur, while if the volume of slag is small we are obliged to depend upon high temperature and basic slag to prevent the union of sulphur with the iron. The effect of sulphur upon the metal is to lower the grade and render it unsuitable for many purposes. Occasionally our slags contain 3% of sulphur when in small volume, falling to 2% when the volume of slag is increased, the grade and quality of the metal remaining the same.

Pig iron contains more or less silicon.

Upon the assumption that the same ores are used in making foundry iron of 2% silicon considerably less limestone flux would be required than in making a mill iron of only 1% silicon.

This is frequently overlooked. The character and quality of the iron made is influenced very materially by the fluxing.

There is less margin for variation in this respect than the mere working of the furnace alone.

The composition of the slag does not indicate either the grade or the analysis of the iron made. With slag of practically the same composition I have made No. I x foundry iron by fracture containing 3% silicon with large crystallization, and iron of close grain with less than 1% silicon.

The percentage of flux employed will be considerably less with the former iron. This is due to the fact that the iron carries off many pounds of silicon that in the latter must be taken care of by the slag in the shape of silica.

As a rule slags high in alumina (exceeding 15%) are undesirable. Silica may vary from 27% to 37%, depending upon the analyses of the ores and fuel, the volume of slag, and the grade and quality of iron desired.

Changes occur in the composition of slags, due to mechanical causes, requiring constant watchfulness and supervision as well as the variations in the ores, limestone and fuel.

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Theoretical fluxing is one thing, but practical fluxing to obtain the most economical results, both as to product, quality of iron, fuel consumption, etc., is quite another thing.

It gives room for the display of no little individuality so far as the management is concerned, and considerable difference, when judged by the final test of all, viz., the balance sheet.

By experience we learn to distinguish slags by their physical appearance. Chemical analysis is too slow and not conclusive, for while indicating a safe slag, so far as the operation is concerned, it does not show the refinements that will suggest themselves to the experienced manager.

The most successful founders of the old school were good judges of slags, quickly observing slight changes and acting promptly, guided by these indications. The most successful Managers of the New School acquired this expert knowledge by actual contact with the daily operations of the furnace.

It is in this particular, along with others of perhaps equal importance, only to be gained by an apprenticeship, long or short, depending upon the individual, that Chemists, attempting to run a furnace on theory, made lamentable failures.

Fuel and Ores.

Up to 1882 anthracite coal was the exclusive furnace fuel east of the Allegheny Mountains, coke being used to the West.

The mechanical difficulties of blast furnace management are much greater with anthracite fuel and the magnetic ores, common to the East, than with coke and the easier working Lake ores.

Indeed, the anthracite district has been a most valuable school, furnishing in the past some of the ablest and most successful managers for Western furnaces.

Some years ago Mr. Chas. Foote, now Vice-President of the Illinois Steel Co., wrote me that the use of Connellsville coke and Lake Superior ore in the blast furnace was heaven on earth to the manager accustomed to anthracite coal and the magnetic ores of New York and New Jersey. He had previously managed the Crown Point furnaces on Lake Champlain, and wrote feelingly, urging me to go West. I did not go West, though strongly tempted, but in the lapse of years cheaper transportation, etc., have brought Lake Superior ore and coke to eastern Pennsylvania, so that we are finding more comfort in living than we did some years ago.

Anthracite coal is dense and solid, consuming on the surface

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only, while coke is porous and light, the combustion permeating the whole structure. Much more coke can be burnt in the same space in the same time, thus increasing the product of the furnace.

Coke offers less resistance to the blast, permitting the use of a larger volume of air per minute with the same engine and boilers and is generally higher in carbon and lower in ash and sulphur. Coal will carry and melt as many pounds of ore as coke.

The fuel consumption per ton of iron for long periods is less with coke for the reason that the furnace can be handled with greater ease and with less danger of mechanical disturbances.

By reason of the more uniform working, the product of the furnace is larger, and the fuel consumed has a larger divisor.

Coal is apt to splinter and decrepitate upon exposure to heat and this tendency is one of the reasons why an anthracite furnace is difficult to control. The dirt thus formed in the furnace not only reduces the amount of combustible fuel reaching the tuyeres, but accumulates along the walls, giving rise to serious mechanical difficulties. Coal dirt, though nearly all carbon, will not burn in the furnace. It is carried off by the slag, sometimes in comparatively large quantities. As the slag flows down the runner from the tapping-hole or cinder notch, into the car provided to receive it, the dirt will separate. The slag being heavier, drops at a different angle, so that the dirt can be collected on a shovel.

When examined, the small particles show the same bright fracture and ofttimes the same bright surface as when mined, thus passing through the fiery furnace unscathed.

It would be an unspeakable blessing if all the coal dirt formed in the furnace was only thus carried off. Unfortunately this is not the case. Sometimes the obstruction caused by its accumulation so seriously impedes the passage of the blast that we are obliged to stop the engine, remove the tuyeres and ravel out the dirt through the tuyere openings, together with other stock, in order to secure passage for the blast and gases.

ORES.

Ores of the same oxidation, belonging to the same class chemically and of essentially the same analysis and physical structure, vary greatly as to their working qualities and their practical value. One may part with its oxygen freely. Another may hold it very tenaciously. Why this is so I do not know, but it is a fact that influences the consumption of fuel per ton of iron more than

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the uninitiated would imagine. By burden is meant the pounds of ore that one pound of fuel will carry, that is, deoxidize and melt, converting it into pig iron. The burden is effected by this quality existing in ores, the difference between the burden at 1.5 lbs. of ore and 1.75 lbs., the grade of iron remaining the same, is ofttimes the difference between running at a commercial loss or a corresponding profit.

The burden is also affected by the richness of the ore mixture, for instance, notwithstanding the larger volume of slag, and, of course, the larger amount of flux usually used with a 50% ore, the furnace will carry a larger burden of a 50% ore mixture than if it was 60%. This is due to the chemical duty to be performed in the way of deoxidation. With a burden of 1.50 lbs. ore yielding 50%, the iron per pound of fuel is 0.75, while with a 60% ore it is 0.90 lbs. iron per one pound of fuel. A correspondingly larger amount of oxygen is to be removed by the gases in the latter case.

Other things remaining the same, while the burden possible with a 60% mixture is smaller than with a 50% mixture, the fuel per ton of iron made will be less with the 60% mixture.

Magnetic ores are usually very dense, and more or less difficult to handle, parting with oxygen slowly.

If ores are too finely divided physically they are a source of trouble. The gases, meeting more resistance in their ascent from the tuyeres, will seek the easiest way of escape. Channels of travel are apt to be formed, or, to speak technically, "the furnace becomes channeled." The effect is that portions of the furnace do not receive their share of the gas, and ore reaches the crucible holding oxygen in combination. This is destructive to the temperature of the crucible and represents a loss of fuel and waste of iron, to say nothing of the irregularities that will develop at and about the boshes, if the unequal distribution is not corrected.

It will be thus seen that good judgment, skill and experience of the manager in selecting and combining ores to accomplish a certain end plays a very important part, and figures largely in the final result, measured in dollars and cents.

Furnaces are not usually run for pleasure, nor for demonstrating any particular engineering device or the working out of any chemical theory, however attractive, but they are run for the sake of profit. Frequently, only too frequently, we are disappointed and sadly disappointed in results, but the man that combines technical knowledge with practical experience and an acquaintance with

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business conditions and requirements, with a due appreciation of their importance, is the man that will show the best final results and is the manager that is sought after. In the blast furnace business a little knowledge is very dangerous. The man, who in his own estimation knows it all, of course has no inducement to learn.

Limestone.

The flux usually employed is either limestone, calcite or magnesium limestone, dolomite. Whether one or the other should be used depends upon circumstances, commercial and technical.

Either will answer, so far as mere running is concerned.

At the same cost per ton of stone, the use of calcite or dolomite will depend in great measure upon the composition of the ore mixture and the kind of iron to be made.

Pig Iron.

The various qualities of pig iron derive their names from the uses to which they are put or from their composition.

Bessemer iron is pig iron of suitable composition to make Bessemer steel.

Basic iron is pig iron suited for the basic open hearth steel manufacture.

Basic Bessemer for the Basic Bessemer converter.

Foundry iron for use in foundry to be remelted and cast into various forms.

Mill iron for use in puddling furnace to be converted into wrought iron.

Low phosphorus for use in acid open hearth steel manufacture and steel castings.

Spiegel, Ferro Manganese and Ferro Silicon are irons of particular composition, for special purposes, and require special ores and treatment in the blast furnace.

Blast.

Furnaces are now operated by volume of air blown per minute as distinguished from the old practice of running by pressure of blast. Pressure is now regarded in the light of one of the valuable indications of internal working or conditions.

Calculated over long periods as measured by piston displacement and exclusive of wastage, between 5 and 6 tons of air are required to produce one ton of iron, and from 60 to 65 cubic feet of air

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to burn one pound of fuel, depending upon the tightness of pipes and fixtures and of the air piston of blowing engine. Atmospheric moisture plays an important part. It is never absent. It enters the tuyeres as vapor of water, calling for an increased amount of fuel to restore the heat absorbed by converting this vapor into its constituent parts, oxygen and hydrogen. Whether the air contains 5 grains moisture per cubic foot or 10 grains, either must be provided for by extra fuel or higher heat of blast, if the temperature of crucible is to be maintained. On an average for any one year, probably 125 pounds of water per ton of iron will be forced into the tuyeres in the shape of vapor, while during the humid summer months it may amount to 200 pounds and over.

This is the reason why more fuel per ton of iron is required during the summer as compared with the winter months.

As a rule less cubic feet of air is required per minute to consume same amount of fuel during the fall, winter and spring months than during the warm months of the year.

Blast Furnace Management.

The modern blast furnace is not an invention, nor a discovery, but a growth. It represents the combined results of numerous experiences, and in itself is the epitome of many a hard-won fight. Sleepless energy and untiring devotion, perseverance in overcoming obstacles apparently unsurmountable, and the forgetting of self, has worked out many unsolved problems. Blast furnace management is fearful drudgery for a man not in love with his work.

No department of iron or steel manufacture calls for closer application and attention to details. It is absolutely continuous. With these qualities lacking, no amount of technical knowledge will win success. The most successful managers have been those that were so absorbed in their work that they never stopped to inquire whether they were being suitably paid.

The results obtained have shown that capital usually seeks out the best talent.

Time does not permit to more than merely mention a few of the improvements. The hearth with open foreheart hand tympe gave place to the German patented, closed front. The principle, however, was worked out in American practice, we finally adopting a modified form of the Lurman device. Fire-brick stoves, an English invention, have practically replaced the cast-iron pipe stoves for heating the blast. Enthusiastic agents, eager to swell their commissions,

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made extravagant claims for super-heated blast, in fact representing that brick stoves were really a panacea for all blast-furnace ills.

They have proven a valuable adjunct, but many failures and serious troubles, scaffolds, etc., followed their introduction in many instances. Numerous minor but important improvements have been made in tuyeres and tuyere fixtures, etc., permitting the replacing of tuyeres in 5 to 10 instead of 30 to 40 minutes.

We have replaced tuyeres with only stoppages of 2 to 3 minutes.

This may be considered incredible by many furnace managers. We now use mechanical appliances for stopping the iron-tapping hole, an invention of Samuel W. Vaughan, manager of the Cambria Iron Co.'s furnaces, thus saving many long stoppages. When a furnace is making iron at the rate of 8 to 10 tons per hour or more, the importance of every minute saved in stoppages can be appreciated.

One of the most frequent and troublesome of the mechanical difficulties is the formation of "scaffolds" in the furnace.

A scaffold is an accumulation on the walls of the furnace, offering an obstruction to the regular and even descent of the material and diverting the uniform distribution of the gases.

Scaffold material is an agglomeration of coal or coke, limestone and ore, partially fused into a solid mass and fastened to the walls. Sometimes scaffolds form a short distance above the tuyeres and gradually grow, extending far up into the shaft of the furnace. At others they commence at the top of the boshes, beyond the reach of the tuyeres, extending upwards and towards the centre of the furnace. Not unfrequently the area of the furnace is so completely occupied by this solid mass that only a small opening, a few feet in diameter is left free from top to bottom.

Of course the operations of the furnace are brought to an inglorious close, but usually only after a hard and laborious fight—a very expensive contest.

On other occasions the obstructions cause irregular working, inferior iron and high-fuel consumption, with excessive costs, but may not be sufficiently serious to put the furnace out of blast. As a rule, however, it does not pay to fight a serious melted scaffold in the hopes of restoring the furnace to good working condition. It may appeal to the professional pride of a manager to continue the fight, but as a commercial proposition it is usually cheaper to stop, shovel out and try again. Scaffolds are not as frequent as for-

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merly, but they are still a serious menace and in one form or another are a constant source of danger and anxiety.

It is estimated that fully 70% of the heat of the crucible is brought into it by the solid materials which in their descent through the furnace come in contact with the highly-heated gas currents.

The effect of any serious interruption to the regular descent of this stock can be thus appreciated. The working or acting area of the furnace being thus reduced by the scaffold accumulation, the flow of gases is confined to a restricted channel. The time of contact with the ores is lessened so that they reach the crucible unprepared for melting, which further lowers the temperature of the crucible. The blast meets with greater resistance, and at times the whole power of the engine fails to drive the air through the furnace The flow of gas failing, the hot-blast stoves are thus deprived of their source of heat, and the temperature of the blast falls. The boilers are fired with coal to maintain steam to operate pumps and keep the engine moving. Finally a passage may be opened and gas again flows through the stoves as the blast finally works its way through the obstruction.

With the lowering of the temperature of the crucible the tuyeres are closed with a semi-fluid mass of iron and slag, communication between the tuyeres and cinder notch or slag opening and the iron tapping hole is obstructed by the partial chilling of the contents of the crucible. Days and sometimes weeks elapse before any iron of merchantable shape and quality is run into the pig beds.

My first experience of a genuine scaffold of the worst kind was a few months after I was entrusted with the responsibility of the management. During an absence of a few days my foreman filled into the furnace a lot of dirty limestone. The limestone shipments had been delayed by wet weather. The centre of the stock pile was reached, which proved to be very dirty from long continued dumping and the daily removal of clean stone from the edge of the pile. For two weeks I never saw a bed. The struggle lasted a month or more. Finally the furnace was restored to normal working condition, much to my gratification, but at great expense and loss to the company. I was thus early impressed with the importance of exercising the most careful watchfulness as to the preparation of the material filled into the furnace—ores, fuel and imestone.

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It was a valuable though a costly lesson, and I have since tried to make good use of it. It pays to use every precaution to prepare the stock before filling, rather than throw additional work on the furnace and run the risks of serious disturbance of its operations.

By experience we learn the various symptoms characteristic of disorders or variations from normal conditions, just as physicians determine disease.

The correct diagnosis is more or less difficult and obscure, as different causes produce the same results. It is just as easy for the furnace manager to draw wrong conclusions and administer the wrong remedy as for the doctor, though he may have the more or less intelligent assistance of his patient.

In the meantime the patient in both cases suffers the penalty of ignorance, however excusable that ignorance may be on the part of the attending expert.

Serious difficulties command the attention of even the average workmen. They mean hard work all around. In many instances less than one-half of the labor necessary to overcome troubles would have prevented them altogether if the warnings had been observed—in other words, if the symptoms had been detected by close application and attention to details. I have always endeavored to impress this fact upon my foremen, by precept and example.

When the furnace is running along smoothly then is the time for the manager to be watchful, to give attention to minute matters and thus endeavor to keep her running regularly.

The average man, under such conditions, is apt to become careless and neglectful. He fails to observe indications of importance, not purposely, but simply from lack of intelligent observation.

Seeing, he sees not, that is, he does not perceive; the mind is dormant. Constant watchfulness and preparation for difficulties that may never come is no more an evidence of undue nervousness than a laudable ambition to improve one's condition is to be confounded with restless discontent, so disastrous to all effort.

The formation of scaffolds is due to many causes, and sometimes they apparently come from no *traceable* cause, simply from "pure cussedness."

Scaffolds may result from the furnace being too hot, as well as too cold; from errors of fluxing or variations in materials, (theory may be all right but practice all wrong); from improper filling of stock, either from badly proportioned bell, neglect in the stock

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house or on the part of the top filler; from long continued use of excessively basic slag, lime scaffolds may be formed, or from use of slags too silicious.

Unexpected stoppages, due to accidents, allowing no time for preparation, may or may not be followed by scaffolds more or less serious.

The gangue of certain ores, fusing to a sticky mass at comparatively low temperature or the use of an easily clinkering coal, may be responsible. A hard and tough white ash coal is required for blast furnaces.

Volume of air blown, area of tuyeres and heat of blast, under certain conditions, are frequently important factors.

Time will not permit any reference to remedies employed to dislodge and remove scaffolds other than to remark that they are sometimes heroic, involving the liberal use of dynamite or practically blowing out or lowering stock below the scaffold, thus loosening it by melting away the foundation and then refilling.

Methods will vary with circumstances and the judgment of manager.

Other disturbances to uniform settling of the stock are known as "arching," "hanging" and "jumping." These invariably produce bad results. If continued, they add to the cost of the iron and at same time cause the production of lower grades and inferior quality. They are not necessarily dangerous.

If not corrected, however, the conditions producing them may lead to a permanent melted scaffold. They may be considered as warnings of something worse to follow.

Accumulations may form on the bosh walls of considerable thickness that in no way interferes with the uniform working of the furnace. If these accumulations are evenly and regularly distributed they serve to protect the brickwork from fusing and from the destructive chemical action of the slag and gases.

This coating at times forms an artificial bosh, more durable than the original brickwork, in fact a graphitic lining.

Furnace "kish" corresponds closely in composition with native graphite, from which plumbago crucibles are manufactured.

Artificial graphite contains more iron than the native, as the following analysis will show:

	Fe. %	SiO_2. %	C. %
Native graphite	1.6 to 4.6	2.4 to 8.6	78 to 85
Artificial or furnace graphite	17.3	2.20	70.74

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When two to three tons of fuel were consumed per ton of iron, or when comparatively large furnaces made but small products, the artificial, or furnace-made bosh lining served to lengthen the duration of the blast. Modern practice, however, does not rely upon this formation to protect the bosh walls, finding it inconsistent with fuel economy and large products.

Modern Construction.

With more intelligent management the common construction previous to 1880 was found inefficient. The changes were gradual, experimental, groping in the dark, as it were.

Each change was made to overcome some special difficulty, as the necessity presented. Probably this side of the subject can be best illustrated by giving a short sketch of the operations of the Warwick furnace. This furnace was first started in 1875.

From 1875 to the summer of 1877 it was in charge of experienced founders, of good reputation, but one scaffold followed another, varied by chilling, about every six months, so that the company was brought to the verge of bankruptcy. The causes were various, but chiefly to the lack of knowledge of the material used.

The ores used and mined by the company were of different composition from those usually employed in the Schuylkill Valley at that time. The largest product of iron for any one week was 190 tons, which represented the average best work of furnaces of the same size in the vicinity. The weekly average, however, of any one blast barely exceeded 50 tons per week for the reasons mentioned.

November, 1877, the furnace was placed in my charge. No changes in construction were made except the substitution of a 7-foot bell in the place of a 5-foot bell. In blowing in, the furnace started excessively hot, causing me much anxiety, but it proved a blessing in disguise, as was demonstrated a couple of years later.

A graphitic coating was formed on boshes, or a scaffold evenly distributed, preserving the brick work without interfering with the working of the furnace. The bosh walls following the construction of that period, were about 3½ feet thick.

In the course of a few weeks the furnace reached a weekly make of 300 tons and over, an unheard-of product at that time for an anthracite furnace of its size.

It created more local excitement and interest than a make of

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1,300 tons does now. When congratulated I replied that I was sorry, as I was afraid that a standard had been made that could not be reached again. We ran 105 weeks without special incident when the inwall gave way, terminating the blast.

The average weekly product was 357 tons.

The furnace was relined, maintaining the same construction, and blown in March, 1880. My troubles now commenced, 1880 being an eventful year. It was a life-and-death struggle, not only for me, but the new method of management was on trial also.

I had earned the jealous hatred of the Old School and my troubles were a source of no little satisfaction to many.

Furnace was blown in March 28, 1880, care being taken not to allow the furnace to start so hot, or grey as it is termed, as the previous blast. A good start was made, the product averaging 368 tons per week, but we only ran six weeks. A new furnace disease was developed, symptoms were not wanting, but their significance was not appreciated until some months later. No serious irregularities were experienced, until upon a certain night following an unusually large cast, the stock settled a few feet from the top, a common occurrence. Following each cast a stoppage was then necessary to close the iron tapping hole. On starting engine it was found that the resistance to blast entering tuyeres was so great that the engine was barely able to run. Gas failed, steam became short, necessitating heavy firing. The tuyeres became a dull red, showing partially fused iron and slag.

Melting practically ceased. Communication between tuyeres-cinder notch and iron notch was cut off. With 14 pounds pressure at the tuyeres, scarcely any flame was perceptible at the open iron or cinder hole. Some of the tuyeres became solid; others melted slowly. The liquid, not being able to sink into crucible, formed a column of sufficient weight to overbalance the air pressure in tuyere pipe and flowed back and filled the pipe with a mixture of slag and iron.

After struggling day and night for several turns I was forced to admit that the furnace was chilled. We proceeded at once to empty the furnace. In cleaning out, it was noticed that from the tuyeres upwards for a distance of ten feet or more the contents were a mass of finely divided dirt, analyzing 47% coal, 46% ore, 7% limestone. Above this mass of dirt the stock was in good condition. Below the tuyeres the crucible was filled with dirt, offering no difficulty to remove.

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There was no iron to contend with.

When furnace was finally emptied, measurents were taken, showing the inwall above boshes to be in good condition and of about the same dimensions as when blown in, but the bosh walls were completely melted, only a light shell on the outer course remaining, about 9″ thick instead of 42″.

It was assumed that the brick used were of poor quality, but this explanation, while the best that could be given at the time, was not satisfactory to me, nor probably to any one else.

There was no evidence of a melted scaffold such as previously described, and "dirt scaffolds or dirt troubles" had not then received a name. During this short blast we made mill iron, and my critics asserted that I was running for sake of a record without regard to the durability of the furnace and that no furnace could stand such treatment.

Repairs were made, a new bosh with different make of brick being constructed. The furnace was again blown in August 27, 1880.

This time I aimed to make foundry iron to meet the criticisms mentioned. It was generally understood that foundry iron formed graphitic protections to the bricks and to this extent prolonged their service. This was undoubtedly true when combined with large fuel consumption and small product, but fortunately or unfortunately for me our product of foundary iron averaged 382 tons per week, a larger weekly product than had yet been reached.

In nine short weeks we had a repetition of the previous blast almost exactly. In the midst of the best working and largest yield, with scarcely any warning, the furnace was again chilled.

Precisely the same conditions were found to exist as before, only more so. The loss of brick work extended higher up the boshes, the mass of dirt being proportionately greater.

To say that I was discouraged does not begin to portray my feelings, but I was determined to kill or cure. In cutting away the brickwork below the mantle, in order to make an opening to remove the stock, I noticed that as soon as the workmen penetrated and air was drawn in through a small hole cinder commenced to trickle down. As the opening was enlarged, the stock was shown to be white hot and in good condition. It then occurred to me that the whole trouble was due to the dirt, and if the dirt had been removed through the tuyeres by ravelling out we would have been

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saved much hot and hard work and the furnace might have continued in blast. At the time, however, it was too late.

When furnace was emptied, the boshes were found to be completely destroyed, but the inwall was in good condition.

While discouraged, I was not hopeless.

I was now satisfied that all my efforts would prove of no avail unless some means could be provided to preserve the boshes.

The walls being thick, as they melted, the area above tuyeres greatly enlarged. The cavities thus formed filled with "dirt" or finely divided ore and coal.

The volume of air blown was not sufficient to fill and keep active the enlarged area. The chilling was due to this mass of dirt being dislodged and settling into the crucible, thus preventing all contact between the air and fuel, the temperature being just sufficient to form a pasty, semi-fluid mass.

My idea was to hold the bosh-walls intact and maintain their shape and dimensions. Mr. P. L. Weimer, of Lebanon, one of the most progressive and intelligent furnace constructors of his time, became deeply interested, and, as a result, the first instance of a water-cooled bosh, in this section at least, was constructed.

This was accomplished by employing a series of vertical pipes encircling the entire bosh and in height about 15 feet above the tuyeres. They were placed against the old shell of brickwork and only a lining of 9″ brick was used in front of them.

Many were the criticisms as to the absurdity of attempting to run a furnace encircled with a flowing stream of water.

The furnace thus constructed was blown in December 15, 1880, continuing in operation 245 weeks, showing a larger product for the blast than had ever been made by an anthracite furnace, average weekly product, including many stoppages and delays, being 416 tons and the total make about 102,000 tons.

Thin bosh walls had been previously used in Germany, but had not attracted much attention in this country.

This blast, terminating September 1, 1885, was not without many incidents of interest and of much hard work, giving opportunity to study the "dirt trouble" or "dirt scaffold," and to become familiar with the symptoms and guard against serious consequences.

By maintaining the size of bosh, the "dirt" was prevented from accumulating in such quantities as to endanger the safety of the furnace. It would take too much time to go into further detail,

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but suffice to say that the folly of thick bosh walls was demonstrated, thus leading to the present construction of thin walls protected with rows of bronze bosh plates, which method was elaborated in the West.

"Dirt troubles" were recognized as one of the conditions coincident with the new practice of comparatively large product and comparatively low fuel consumption, but more particularly confined to the use of anthracite coal. They, however, are not unknown to the coke furnaces.

By close watching we are now able to control them, but so far have not succeeded in preventing the formation of the dirt.

The blast commencing December, 1885, was of 180 weeks' duration, averaging 598 tons per week. New and larger iron stoves were added to the equipment during the repairs, enabling a larger volume of air to be blown than previously.

This, together with the use of one quarter coke addition enabled us to increase our product. We had our "ups and downs," the average results, however, being fairly satisfactory. The bosh coils were used to maintain the shape and size of the boshes, 18 inches of brick being placed in front of them.

The blast October, 1889, to July, 1892, lasted 144 weeks, averaging 744 tons per week. A new stack had been constructed, 70 feet high, instead of 53 feet, and bosh walls 18 inches thick, protected with water coils and strengthened with a bosh jacket. We had several serious "dirt troubles." With each improvement in construction, designed to overcome the troubles, the product of the furnace was increased so that relatively we were in the same position in this respect as before. However, while we could not prevent the accumulations, we learned to handle them to better advantage.

Several times during this blast we were obliged to use oil blowpipes to melt out chilled tuyeres and open the iron tapping hole, closed with chilled iron, remove the tuyere and ravel out the stock which consisted chiefly of fine dirt.

For several days little or no merchantable iron was made, but finally in each instance the furnace was restored to normal working condition.

During the blast from October 1, 1892, to September, 1896, 206 weeks, we made a product of about 204,000 tons iron, using half coke and half coal as fuel.

In the first six months we had several serious experiences from

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"dirt," due in great part to over-confidence in the high heats of blast from our new brick stoves and the larger use of coke. It was assumed that the high heats of blast possible with brick stoves, as compared with cast-iron pipe stoves, would enable us to contend with "dirt accumulations" without taking the usual precautions. Greater confidence was also felt in the bosh construction, we having substituted bronze bosh plates for the water coils. Only 4″ of brick work was in front of the bosh plates so that the bosh could only enlarge 8″ in diameter, thus leaving less room for the lodgment of dirt. During the first six months we learned that this confidence was misplaced. Our old enemy was as much in evidence as on previous occasions.

Our weekly product of iron reached 1,000 to 1,100 tons.

The dirt accumulation formed higher up, lodging at the top of the boshes, above the bosh plates in the widest part of the furnace.

Neglecting in a measure our usual precautions and taking chances or risks, we suffered in consequence. The average furnace employee is naturally conservative, opposing on principle every innovation and charging every trouble to any new device or construction that may have been adopted. He forgets the past and is constantly citing the "good old times," as better educated and better informed people are in the habit of doing.

The new bosh plates were condemned as being responsible for the irregular working, and this belief caused a hopeless discouragement to take possession of my principal men, unfitting them for effective work, notwithstanding all the records I was able to show to the contrary. They could not or would not be convinced.

On one occasion an opportunity occurred to prove conclusively that bosh plates were innocent of all blame.

Following an unusual large cast of iron, as on previous occasions, the dirt accumulation loosened and moved down to tuyeres so that the furnace would not take any blast.

Instead of attempting to force blast into the furnace and thus closing the tuyeres with semi-fused iron and slag, the engine was stopped and several tuyeres removed before the dirt was fused into a sticky mass. Bars and hoes were used to remove the stock.

In a short time we were almost overwhelmed with a flow of red hot dirt flowing like so much red hot pewter sand.

This was removed and the ravelling continued until the lower part of furnace was completely emptied, but there was no move-

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ment of the stock on top of furnace. Dynamite cartridges were used above and below to cause settling, but with no effect.

The men were cautioned to keep away from tuyere openings, for fear of accident in case the stock should drop suddenly and drive out a volume of burning gas. No movement occurring, my foreman and myself cautiously approached a tuyere opening and, reaching forward, looked up into the shaft of furnace. The boshes were found to be perfectly clean and in beautiful shape, the bosh plates were seen to have nothing whatever to do with the trouble, as an arch had formed fully fifteen feet above the top row of plates.

The skew back of this arch was later located more exactly by drilling holes through the brickwork.

Had this arch given way while we were at the tuyeres openings we would have been cremated.

The tuyeres were replaced and the engine started.

Gas issued from the top of furnace. The blast pressure was low. This gradually increased, becoming quite high and the flow of gas almost ceased again. Conditions assumed a serious aspect, for unless this arch broke away the blast was ended.

Gradually the pressure lightened, showing that the blast was making its way through the arch, and finally, with a terrible roaring noise, the stock settled or jumped, making a pyrotechnic display that would have been interesting under more favorable auspices.

Red-hot coke, in large quantities, was driven out of the top of the furnace (the bell fortunately being open) down through the gas flues and up through the stove checker work and chimnies, for many feet into the air. This occurred about midnight.

The scene for a minute or two, with the mass of fire and gas, was calculated to cause dismay, if we had had time to think.

Fortunately no one was injured.

The furnace resumed working and commenced to melt regularly.

In the course of a few days, after more or less trouble with a high bottom and chilled tapping hole, necessitating the use of the oil blow pipe, the furnace was in normal working condition.

After this we did not take any more chances. All were convinced that the bosh plates were not the cause of the irregular working, and with renewed courage we went to work to combat our old enemy with the confidence born of many victories.

If we could not prevent the dirt accumulating, by carefully watching the symptoms, we could prevent serious consequences following.

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So far the present blast commencing December, 1896, has been free from any serious troubles of the kind, but only for the reason that we are constantly on the watch and do not permit the slightest symptoms of disorder to pass unnoticed.

We are now making 1,200 to 1,400 tons iron per week—the total product for 1897 being 63,137 tons—as compared with 17,148 tons for 1878.

Careful, experienced and intelligent nursing is just as important in the modern furnace as in the modern hospital.

THE MINOR PLANETS.*

By JOHN K. REES.

During the centuries that preceded the invention of the telescope the unaided eyes of the star gazers had mapped with fair accuracy the positions of a few thousand stars. They early saw that several stars were different from their fellows, which retained their *relative* positions without apparent change year after year. A few stars were observed to move or wander among the others and the wanderers they styled *Planets*.

Studying the recorded observations of Mercury, Venus, Mars, Jupiter and Saturn led Copernicus in the middle of the sixteenth century to declare his theory, that, about the sun as a center these planets moved, having the earth as a companion.

The moon was known to be a satellite of the earth. Thus six planets and one satellite were recorded.

The beginning of the seventeenth century brought the wonderful invention of the telescope. Galileo with his "Optick tube" discovered in 1610 four moons of Jupiter. During the century that followed this discovery the astronomers with their cumbrous telescopes found that Saturn was accompanied by interesting companions.

J. D. Cassini and Huyghens observed five moons, and the latter was first to see that Saturn was encircled by a wonderful ring

* From a popular lecture before the New York Academy of Sciences on March 29, 1897.

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system, making it the most ornate and curious member of the solar system.

William Herschel, working with a reflecting telescope of his own construction, startled the world by adding a new planet to those which had been known from and before "the dawn of history." The discovery of Uranus on March 13, 1781, "had the surprising effect of utter novelty." In 1787 Herschel found that this new planet had two moons and in 1789 he added two new satellites to Saturn's complex system.

All the other attendants of the planets have been discovered during the present century, and on September 23, 1846, Dr. Galle, of the Berlin Observatory, directing his telescope to the part of the heavens indicated by the calculations of Le Verrier, added the outermost planet to our system.

Neptune was discovered in 1846 by Lassell to have one moon, and the same observer in 1851 provided Uranus with two additional satellites.

Our own Bond at Cambridge in 1848 gave Saturn his eighth moon. The year 1877 was made memorable by the splendid discovery of Asaph Hall of two minute satellites of Mars.

It remained for keen-eyed Barnard, of the Lick Observatory, using the great telescope there mounted, to find that giant Jupiter was attended by a very small fifth moon. This discovery was made 282 years after Galileo first showed the four moons that are easily visible.

The solar system as known at the close of the eighteenth century consisted of seven planets and fourteen satellites or moons; at the end of the present century the number is increased by one planet, seven satellites and more than 400 minor planets, numerous comets and meteor swarms.

The illustrious Kepler, as long ago as the beginning of the seventeenth century, while groping for a law of the planetary distances, was almost reduced to despair by the anomalous space between the orbits of Mars and Jupiter. He finally gave up the idea "of reconciling *the actual* state of the planetary system with any theory he could form respecting it, and hazarded the assertion that a planet really existed between the orbits of Mars and Jupiter, and that its smallness alone prevented it from being visible to astronomers."

In 1772, nine years before Herschel's discovery of Uranus, Pro-

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fessor Titius, of Wittenberg, pointed out "the existence of a remarkable symmetry in the disposition of the bodies constituting the solar system."

He showed that if we write down the numbers 0, 3, 6, 12, 24, etc., each of which, except the second, is two times the previous number, and add to each of these numbers the constant 4, we will get a series of 4, 7, 10, 16, 28, 52, etc. These first six numbers gave with fair accuracy the relative distances of the then known planets from the sun, the earth's distance being represented by the number 10. With one remarkable exception (the exception that puzzled Kepler in his studies), there was no planet known at the distance 28.

Professor Bode put in this place a hypothetical planet. The discovery of Uranus in 1781 at a distance which nearly complied with the law strengthened belief in the truth of the law. Von Zach in 1785 actually calculated elements for this "unseen and unfelt body." For fifteen years he kept in mind the need of a careful search for this unseen body, and in September, 1800, he organized at Lilienthal a force, jocularly named by him "Celestial Police," consisting of himself and five other astronomers as prime movers, who were to call in the aid of others, "for the express purpose of tracking and intercepting the fugitive subject of the sun." The search scheme provided that the heavens, eight degrees on each side of the equator, should be divided into twenty-four zones. Each zone was to be placed under the care of a single observer. The association was pushing its arrangements as rapidly as the lack of postal, telegraph and railroad facilities would allow, when they were surprised and gratified by the news that the sought-for planet had been discovered, but by an astronomer who had not been looking for the body, but had been carefully observing the heavens for another purpose.

Professor Piazzi, at the observatory of the University of Palermo in Sicily, had been working for nearly ten years to form a star catalogue. On the first night of the present century, January 1, 1801, he was observing the stars in the constellation of Taurus, unaware that to him had been assigned a zone by the Lilienthal enthusiasts. He found an eighth magnitude star which the observations of the subsequent nights proved to be moving slightly among the surrounding stars. He thought he had discovered "a new kind of comet without tail or coma," only a nucleus. Piazzi

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continued to watch the suspicious body until a serious illness compelled him, on February, 11, 1801, to give up for the time being all work. He had previously, however, sent letters to Oriani in Milan and to Bode in Berlin. These important messages were very slow in reaching their destinations. In those days of war, intercommunication was slow indeed. The letter to Milan consumed 72 days and that to Berlin two weeks less. "The delay just afforded time for the publication by a young philosopher of Jena, named Hegel, of a "Dissertation" showing, by the *clearest light of reason*, that the number of planets *could not exceed seven*" (the number then known), and exposing the *folly* of certain *devotees* of *induction* who sought a new celestial body merely to fill up a gap in a numerical series.

As soon as Bode read the letter he concluded that the body seen by Piazzi was the looked-for planet. The news stirred deeply the scientific world. In the meantime the planet had moved so close to the sun as to be no longer visible; then alarm was felt lest this new planet should be lost, for the observations of Piazzi were not sufficient to enable the mathematical astronomers of those days to compute the path of the new body among the stars. At this juncture the great mathematician Gauss came to the rescue. He was twenty-five years of age and was engaged in teaching at Brunswick. This interesting problem made Gauss an astronomer and gave to the world the *Theoria Motus*. He devised new methods and was able to compute from Piazzi's observations the positions the planet would be in at subsequent dates. Rain and mist, sleet and clouds, prevented proper observations until the last night of the year, when on a clear and cold night the star was found by Von Zach (at Gotha) very close to the place computed by Gauss. It was seen by Dr. Olbers at Bremen the next night, just a year from its discovery. Piazzi named the planet Ceres-Ferdinandea, after the tutelary goddess of Sicily and in honor of the king of Naples. Astronomers have retained the name of Ceres only.

The "celestial police" had at last arrested the fugitive and had taken her picture for the rogues' gallery; she could thereafter never get away again, her habits and ways of moving had been unerringly determined.

The first year of the new century had been well marked. The mean distance of Ceres was found to be 27.67. The distance required by the law of Titius was 28, the earth's distance being 10.

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On March 28, 1802, Dr. Olbers found, near the place where Ceres had been discovered, a second planet. Gauss again made the calculations and showed that the new planet moved in a very eccentric orbit, inclined at the extraordinary angle to the ecliptic of nearly thirty-five degrees and at about the same mean distance, but in other respects was unlike Ceres. Dr. Olbers named the new planet Pallas.

The astronomers had begun their search to find a planet in the great gap between the orbits of Mars and Jupiter, expecting to discover one body; they were surprised by finding a second. Both bodies were very small, very much smaller than the old planets and smaller even than the moons of Jupiter. Dr. Olbers, on considering the comparative minuteness of these new members of the solar system and the fact that their orbits came very near to each other at the intersection of their planes, suggested that Ceres and Pallas might be the fragments of a larger body which had been disrupted by an internal explosion. This theory held its ground for some time, and gave a new impulse to the search. If, Dr. Olbers thought, an explosion had occurred, there ought to be more fragments. The eccentricities and inclinations of the various orbits might be different, but their mean distances should be the same and the orbits should intersect at two points, where the explosion took place and at the opposite point. Dr. Olbers proposed, therefore, to examine most carefully every month the two portions of the heavens where the orbits of the so-called fragments already seen crossed each other—the northwestern part of the constellation of the Virgo and the western part of Cetus.

In the meantime Professor Harding, of Lilienthal, was constructing a map of all the small stars near the paths of Ceres and Pallas in order to aid in keeping track of these bodies. While thus engaged he discovered the third member of the group on September 1, 1804. This body was found near the place where Olbers' theory looked for it. Harding, "deeming it appropriate to place Juno near to Jupiter," selected that name for the third minor planet.

Dr. Olbers continued his search with great industry, but it was not until March 29, 1807, that he was fortunate enough to discover the fourth minor planet. Gauss gave it the name Vesta. It is the brightest of these bodies and may, under very favorable circumstances, be seen by the naked eye. Olbers considered the finding

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of Vesta almost a proof of the truth of his explosion theory. He kept up the search for nine years, when, not meeting with further success, he ceased his scrutiny. We now know that he looked for too bright stars. He confined his searches to the seventh and eighth magnitude stars.

It was not until 1831 that persistent searching was resumed by Herr Hencke, of Driessen. This persevering amateur astronomer compared certain portions of the heavens with the maps of the Berlin Academy. "These maps extend fifteen degrees on each side of the equator and contain all stars down to the ninth magnitude and many of the tenth." Hencke made some of these charts more complete by inserting fainter stars. For nearly fifteen years he examined the heavens without success, but on December 8, 1845, he discovered the fifth minor planet. Professor Encke, at the request of the discoverer, named the new body Astræa.

The amateur of Driessen discovered another planet July 1, 1847, and Hind, of England, added two more to the list during the same year. 1847 was the first year in which more than one body had been found. Four were picked up from 1801 to 1807; then for more than thirty-eight years none were found, because the astronomers looked for too bright stars and had no adequate maps. Since 1845, and the double successes of Hencke and Hind, the search has been pushed on vigorously. The new discoveries have shattered the explosion theory of Olbers, and no sufficient theory has taken its place. By the aid of better telescopes, more observers, finer maps, and especially by the assistance of photography, the number of minor planets has been increasing with amazing rapidity until to-day (March 29, 1897) 422 are on the list as observed sufficiently to enable the computers to figure out the orbits. There are besides about 28 planets that have been insufficiently observed, so that their orbits have not been calculated. The searcher for a new minor planet must know the position of every one of the celestial 400 in order to be certain that he is not looking at a known body.

The number assigned to a minor planet corresponded exactly with the order of discovery when discoveries were few. This is not the case at present, but it is quite closely so. Now that they are so numerous, some time may elapse before the planet is proved to be a new one. In the meantime another may be discovered and shown to be new before the proofs are in hand as to the first.

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In this case the first is made last and the last first; for example, Max. Wolf at Heidelberg photographed two planets on the 18th of March, 1892, and one on the 21st; Charlois on the 22d at Nice and Palisa on the19th at Vienna, each picked up with his telescope a supposed new planet. The last were shown to be new before Wolf's were decided upon. Thus we have

No. 326 by Palisa,	discovered	March	19,	1892.
No. 327 " Charlois,	"	"	22,	"
No. 328 " Max Wolf,	"	"	18,	"
No. 229 " " "	"	"	21,	"
No. 330 " " "	"	"	18,	"

Up to the present time there have been 44 successful observers. Ten of these have discovered 9 or more planets; fourteen have discovered between 2 and 9, and twenty have discovered one each. At the head of the list stand Palisa of Vienna and Charlois of Nice, each credited with 83. Third in order of number discovered comes our own lamented Dr. Peters, of the Litchfield Observatory of Hamilton College, N. Y., with 47; then follows Max Wolf of Heidelberg with 33, and Luther of Dusseldorf and Watson of Ann Arbor with 24 and 22 respectively.

Before the Atlantic cables were laid, and before telegraphic communication was arranged between observatories, there were several cases of independent discoveries. Of the 422 little planets whose orbits are known, 340 were discovered in Europe, 76 in the United States and 6 in Asia. The 340 credited to Europe are divided as follows: Germany 155, France 158, Great Britain 14, Italy 13. Down to November 28, 1891, when Max Wolf first tried photography, 322 asteroids (as Herschel named them) were discovered by use of the telescope; since the date named only 7 have been added by the same means. Photography has picked up 93 in the last five years. Thirteen little planets were found between 1801 and 1851, 409 since 1851. The year 1892 was the most prolific, 28 being added to the list; of these 4 were by telescope and the rest by photography. 1893 comes next with 27, all but one obtained by the telescope. 1894 brought 20; 1895, 11; 1896, 13. In these statistics we are dealing only with the planets whose *orbits* have been calculated and published.*

* There are 23 dates on which 2 planets were found; 7 of these cases included the observations of two men; the others of one man. On September 18, 1893, Charlois found 3; September 25, 1892, Wolf got 4, and on January 7, 1896, Charlois at Nice and Wolf at Heidelberg brought down 9 by photography.

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The naming of the minor planets has given considerable trouble. Following the old system of naming the major planets and satellites after deities in the Greek and Roman mythologies, the first discovered little planets were called Ceres, Pallas, Juno, Vesta, Astræa, Hebe, Iris, etc. This system was in the main continued until the multitude exhausted the names; then names were given without any system, but always feminine names.

Number (12) discovered by Hind in London was named Victoria; (20) was styled Massalia after the ancient name of Marseilles; so (21), the first asteroid found at Paris was named after the ancient Gallic capital Ţutelia; (54) was called Alexandra after Alexander von Humboldt; (67) was found by Pogson at Madras and called Asia; (323) was the first minor planet discovered by photography on December 20, 1891. Max Wolf named it Brucia after Miss Catherine W. Bruce, of New York City, who has done so much for astronomy in an appreciative and generous manner. Harvard Observatory is indebted to Miss Bruce for its new photographic doublet of 24 inches diameter of object glass and about 11 feet focal length. Max Wolf was made happy by a gift from the same source of a fine photographic outfit. Vassar College Observatory owes much to Miss Bruce for instruments. New York City has reason to be proud of its two patronesses of astronomy, Mrs. Henry Draper and Miss Catherine W. Bruce. (325) was christened Heidelberg by Wolf; (327) was a telescopic discovery by Charlois on March 22, 1892. In honor of the proposed celebration of the 400th anniversary of the discovery of America, he called the planet Columbia. (334) was named by Wolf, to do honor to the proud city that created the splendid exposition, Chicago. Wolf has honored California also in naming (341). The last four to receive names are called Elizabetha, Edburga, Bertholda, Zähringia. Quite a number, happily, have not been named yet. In 1849 Dr. Gould proposed to represent the little fellows by numbers inclosed in a ring; this system has been used, though the naming continues.

Just as in the case of the major planets, each minor planet was given a symbol at first, but the rapid increase caused this method of marking to be given up.

The apparent diameter of the largest asteroid is less than one second of arc; to look at it is like viewing a marble 3–10 of an inch in diameter at the distance of one mile. The best determinations of the diameters of the four largest were made in 1894 and

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1895, by Barnard, with the filar Micrometer of the 36-inch equatorial of the Lick Observatory. These observations gave the diameters as follows:

(1) Ceres, 485 miles; (2) Pallas, 304 miles; (3) Juno, 118 miles; (4) Vesta, 243 miles.

It is surprising to find Vesta, the brightest of the four, so much smaller; this has been proved to be due to high reflecting power of the surface. Its reflecting power was found by Barnard to be more than four times as great as that of Ceres, which is the largest.

The rest of these bodies are probably smaller than the four named; some of them no bigger than a terrestrial mountain. A minor planet 12 to 13 miles in diameter would compare with our earth as a sand particle to a sphere one foot in diameter. A body weighing 200 pounds on the eaath's surface would, on (188) Menippe, weigh less than five ounces. A weight which falls here 16 feet in the first second would there fall ¼ of an inch. A person might there leap to a height of several hundred feet, in which case he could not return in much less than an hour; but "Of such speculations there is no end," as Sir John Herschel remarks.

The mean distances of the asteroids from the sun differ greatly; Medusa (149) has the smallest mean distance, 2.13 times the earth's distance from the sun, or about 198 millions of miles; Medusa makes its circuit in the shortest time, 3 years and 40 days. Thule (279) has the greatest mean distance, 4.26 times the earth's distance from tne sun, or about 400 millions of miles; it has a period of nearly nine years. The average asteroid is 246 millions of miles from the sun, and revolves about it in 4⅓ years. The inclinations of the orbit planes to the ecliptic average about 8 degrees, one degree more than the inclination of Mercury's orbit to the ecliptic, but Pallas (2), as we have previously remarked, has an inclination of 35 degrees and Euphrosyne (31), of 26½ degrees.

Several of the orbits are very eccentric; Aethra (132) has almost a cometary eccentricity of 0.34. A dozen others have eccentricities or about 0.30. These furnish a connecting link between comets and planets. In the case of Aethra its greatest distance is twice its least distance from the sun: 312 millions and 156 millions of miles.

"The complexity of the interwoven orbits has grown almost in the numerical proportion of discovery." "Yet no two intersect,

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because no two lie exactly in the same plane, so that the chances of collision are at present *nil.* There is only one case, indeed, in which it seems to be eventually possible." M. Lespiault has pointed out that the curves traversed by Fides and Maia approach so closely, that a time may arrive when the bodies in question will either coalesce or unite to form a binary system." The breadth of the zone in which the minor planets travel is about 275 millions of miles. They go out dangeronsly near Jupiter and reach inward to Mars. The powerful attractions of these bodies, especially Jupiter, perturb the little planets very greatly and make the calculations in regard to their orbits and positions extremely difficult. This labor has been carried on for years by a special bureau in Berlin. The trouble is so great that some astronomers have suggested that all but the most important be allowed to lose themselves; but the scientific sentiment is against such a policy. The future ought to behold a plan whereby the enlightened nations will join hands in dividing up the labor. These are the days of international agreement and enterprise in all things, and surely science should share in the great benefits to be certainly derived from international coöperation.

There are gaps in the zones of the asteroids; these gaps appear to be at such distances as would make the planet circulating therein have a period commensurable with Jupiter's period. The result would be that Jupiter would get a frequent pull on such planets and eventually so disturb them that they would crowd into the adjacent region, where the disturbing influence would be less felt. The most remarkable gap seems to be between 3.27 and and 2.50,* where the mean motion is two and three times as great as Jupiter's. There is another marked gap between 3.50 and 3.90, a space of about 37 millions of miles in width, in which circulate only one or two known asteroids. This gap covers the spaces in which asteroids must move in order that three revolutions of Jupiter may correspond to five revolutions of the minor planets, four of Jupiter to seven of minor planets, five to eight, five to nine, and seven to eleven, etc.

That the law of commensurability of orbits has greatly influenced the present distribution of the asteroids, as suggested by Kirkwood, there seems to be no room for doubt. The recent investigations of the German astronomers show that as the number of the asteroids increases, this law exhibits itself more strikingly.

* The earth's distance from the sun being represented by 1.

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The very rapid augmentation in the number of minor planets indicates that there may be thousands or even millions in the zone; with more powerful telescopes and more sensitive plates we may hope to find many of these thousands. And perhaps the same agencies will discover asteroids between the orbits of all the planets. It may happen that some one will show that under the influence of Jupiter a parabolic comet may be trapped into becoming an asteroid, or an asteroid may be so powerfully affected as to be compelled to move so close to the sun as to become comet-like in appearance and orbit.

As to the origin of the asteroids, present opinion furnishes three theories: "One is: that the material, which according to the nebular hopothesis ought to have been concentrated to form a single planet of the class to which the earth belongs, has failed to be so collected, and has formed a flock of small separate masses. It is now generally believed that the matter which at present forms planets was once distributed in rings like those of Saturn. If so, this ring next outside of Mars would necessarily suffer violent perturbations from the nearness of the enormous planet Jupiter, and so would be under very different conditions from any of the other rings. This, as Professor Peirce has shown, might account for its breaking up into many fragments. A second view is that a planet about the size of Mars has broken to pieces. It is true, as has been often urged, that this theory in its original form, as presented by Olbers, cannot be correct. No single explosion of a planet could give rise to the present assemblage of orbits, nor is it possible that even the perturbations of Jupiter could have converted a set of orbits originally all crossing at one point (the point of explosion) into the present tangle. The smaller orbits are so small that, however turned about, they lie wholly inside the larger orbits, and cannot be made to intersect them. If, however, we admit a *series* of explosions this difficulty is removed; and if we grant an explosion at all there seems to be nothing improbable in the hypothesis that the fragments formed by the bursting of the parent mass would carry away within themselves the same forces and reactions which caused the original bursting, so that they themselves would be likely enough to explode at some time in their later history."

Kirkwood has suggested the third theory, the same cause which separated the head of a comet into several pieces, viz.: The un-

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equal tidal action on the different parts of the comet by the sun's attraction, may in the distant past have acted to divide the tenuous primitive masses. These tenuous masses of nebular matter were left behind by the contracting sun, and later his tidal influence was so powerful as to break several of the masses into pieces. Kirkwood, Tisserand and the German astronomers have found weighty evidence in favor of this view. It would seem proper, however, to consider that we might apply all three theories at once; the facts rather favor such a combination.

"At the beginning of the 19th century this new field of research was opened to astronomers. A class of bodies till then unseen by the human eye and unimagined by the human brain; a class, indefinite in number, perhaps more difficult to enumerate than the stars as seen without a telescope; a celestial cluster, in short, within our own solar domain was first revealed to telescopic view."

What do these asteroids indicate in regard to the physical history of planets or the laws by which the heavenly bodies are controlled? If "the universe is a book written for man's reading," only patient study may resolve the problem contained in these mysterious leaves.

AUTHORITIES CONSULTED.

(1) Grant's History of Physical Astronomy to 19th Century.
(2) Clerke's History of Astronomy during the 19th Century.
(3) The Asteroids. Kirkwood.
(4) Bulletin Astronomique, 1894–1897, Paris.
(5) Annuaire du Bureau des Longitudes, 1897.
(6) Astronomical Journal, Cambridge, Mass.
(7) Proceedings of the Astronomical Society of the Pacific.
(8) Monthly Notices, Royal Astronomical Society, London.
(9) Observatory, London.

Bulletin Astronomique for January, 1896, shows that Charlois, at Nice, between November 18, 1894 and August 29, 1895, exposed 41 plates on suitable parts of the sky. Only nine failed to show traces of objects sought. In the remaining 32 plates 44 known planets and 11 new ones were recognized. 4 of the new ones were of 11th magnitude, 3 of 12th, 1 of 13th and 3 of 14th. Eleven of the old planets were of the 10th magnitude or brighter.

Max Wolf's photo telescope was made with a 6-inch portrait lens, 30-inch focus, 70 square degrees of field. Two photographs of each region were taken; exposure, each 2 hours. One way of comparing the two of same region is to compare a positive with a negative, films being in contact. The two trails will be seen in continuation of each other if they are real. Another method of detecting the trails is to employ a stereoscope. The changed position brings out the trail in relief. Measures of these photographs do not give accurate positions, but serve as guides. See *Nature*, Vol. 53, p. 162, and *Astronomische Nachrichten* 3319.

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AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

By ALFRED J. MOSES, Ph.D.

CHAPTER IX

THE OPTICALLY UNIAXIAL CRYSTALS (Continued).

VI. OPTICALLY UNIAXIAL CRYSTALS IN WHICH THE OPTIC AXIS IS A DIRECTION OF CIRCULAR POLARIZATION.

In certain hexagonal and tetragonal crystals monochromatic plane polarized light transmitted in the direction of the crystal axis *c* (optic axis) is not extinguished by *crossed* nicols, but is extinguished after a definite rotation of the analyzer.

Plane, Circular and Elliptical Polarization.

If light with vibrations in one plane is decomposed into light with vibrations in two planes at right angles, any ether particle in the path of two interfering rays, p. 134, will be acted upon by two vibrations which will be at right angles, but, generally speaking, these will be neither of the same phase nor of the same intensity. The effects are analogous to those produced upon a swinging pendulum by a second impulse at right angles to the first.

1°. In general the resultant motion is elliptical and the light is *elliptically polarized.* For instance, the light emerging from a doubly refracting plate in a polariscope is in general elliptically polarized.

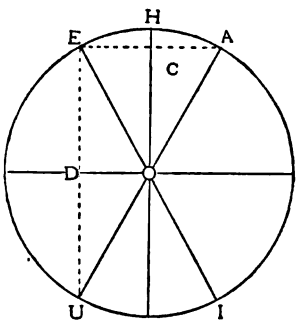

Fig. 247.

2°. If the phase difference is a half vibration ($\frac{1}{2}\lambda$), or an entire vibration, the resulting motion is in a straight line and the light is *plane polarized.* For example, Fig. 247, if AU is the original direction, OD and OC, the components at right angles $\frac{1}{2}\lambda$ apart, the resultant motion will be EI equal AU, but not in the same direction.

3°. If the vibrations are of equal amplitude, but possess a phase difference of $\frac{1}{4}\lambda$, that is, if one vibration is at the center of its swing when the other reverses its direction, the

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resultant motion is circular and the light is *circularly polarized.* For example, yellow rays emerge from a quarter undulation mica plate in the polariscope circularly polarized.

In the Fresnel rhomb, Fig. 248, the index of refraction of the glass and the angles of the rhomb are so related that a plane polarized ray S, normally incident, experiences a total reflection at E and another at U at such angles that at each reflection there is developed a phase difference of $\frac{1}{8}\lambda$ between the component vibrating in the plane of reflection and that vibrating in a plane at right angles thereto. That is, the vibration of any particle in the emerging ray T is the result of two component vibrations at right angles with a phase difference of $\frac{1}{4}\lambda$, but not in general of equal intensity. The ray is therefore *elliptically polarized* and if examined by a nicol will show variations in intensity, but never complete extinction.

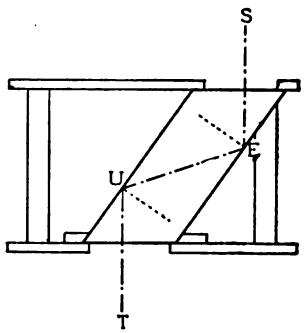

FIG. 248.

If the plane of vibration of the incident light is at 45° to the plane of reflection of the rhomb, the component vibrations will be equal in intensity, the emerging light will be *circularly polarized*, the analyzing nicol will show no variation in intensity.

If two rhombs are used, the four successive total reflections develope a phase difference of $\frac{1}{2}\lambda$, that is, the impulses are in the same straight line, the emerging light is *plane polarized* and is extinguished whenever its plane of vibration coincides with that of the long diagonal of the nicol.

ROTATION OF THE PLANE OF POLARIZATION.

Two circular vibrations in opposite directions in the same plane are equivalent to a straight lined vibration of double amplitude and *vice versa.* A particle at A, Fig. 249, simultaneously subjected to two motions tending to carry it in any time t, at a uniform angular velocity through the equal arcs AR and AL would evidently in this time travel along the path $AU = 2AS$, for the component SL and SR at right angles to AS are equal and opposite and of no effect. For the arcs ART and ALT, the distance travelled would be $AN = 2AT$. Conversely, the vibration AN is equivalent to the two circular motions ART and ALT.

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If a plane polarized ray be decomposed by any substance into two rays circularly polarized in opposite directions, these rays, in traversing a plate of given thickness, will develope a phase differ-

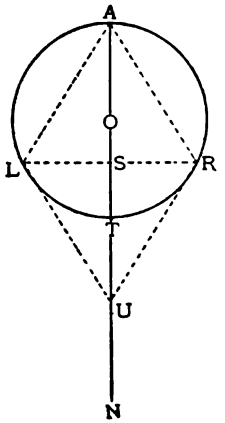

FIG. 249.

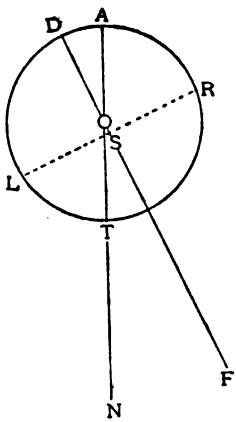

FIG. 250.

ence,* and on emergence will combine to a plane polarized ray.

The planes of vibration (or of polarization, see p. 128) *of the incident and emerging rays will not be parallel.*

Let *AN*, Fig. 250, represent the vibration of the incident ray, *R* and *L* the advance points of the emerging rays at the moment of emergence, then will *DF* be the vibration of the emergin gray, *D* being midway between *R* and *L*, for only for this direction will the components *SL* and *SR* neutralize each other.

The rotation for a thickness of 1 mm. is usually denoted by a and for any other thickness l, by la. The value of a in terms of the wave length and the indices of refraction of the two circularly polarized rays† is $a = \frac{\pi}{\lambda}(n''-n')$.

THE OPTIC AXIS A DIRECTION OF DOUBLE REFRACTION.

In this division of uniaxial crystals, any incident plane-polarized ray transmitted in the direction of the optic axis, is converted into two diverging rays circularly polarized in the opposite sense (direction).

From the formula above given, the divergence $n''-n'$ may be calculated, or, even when minute as in quartz, it may be experimentally shown by the method of Fresnel with three prisms of quartz cut as in Fig. 251.

* Due to difference in velocity and length of path.

† Th. Liebisch. *Grundriss der Phys. Kryst.* 1896, p. 124.

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In *A P D* the right-handed ray is the faster, reaching *P A C* it is the slower, hence is bent towards the normal while the left-handed ray is bent away from the normal. Reaching *A C E* the right is

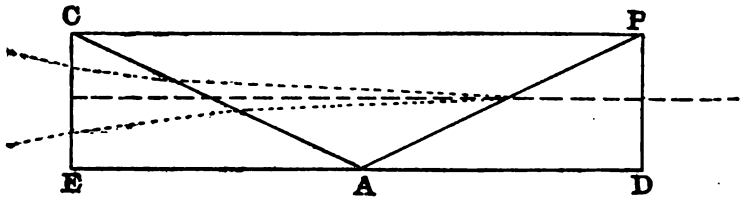

FIG. 251.

again the faster and is bent from the normal while the left is bent towards it, and finally on emerging both are bent from the normal: all changes acting to increase the divergence until with $PAC = 152°$ a divergence of 4° is reached which can be measured by a goniometer.

It can be shown by a nicol that these emerging rays are circularly polarized and in the opposite sense.

RAY SURFACE.

The ray surface is closely that of the preceding division, but with the ellipsoid and sphere not quite in contact at the optic axis, one of them a little flattened, the other a little drawn out.*

It is probable that there is a grading from plane polarized light transmitted normal to the optic axis, through elliptically polarized light, the eccentricity of the ellipse decreasing with the angle between the transmission direction and the optic axis, to circularly polarized light in the direction of the optic axis.

The optic axis remains an axis of isotropy, every diameter perpendicular to it is an axis of binary symmetry, but there are no planes of symmetry because the direction of rotation in corresponding shells at the extremeties of the optic axis are reversed.†

The division is therefore limited to crystals in which the crystal faces are not symmetrical either to any plane or to the centre. A further condition seems to be that the right and left forms shall be "enantiomorphs" (the one can not by rotation about any axis be

* Lang with quartz shows the velocity of the ordinary rays near the axis is not quite constant and that the extraordinary does not follow exactly the Huyghens law of common uniaxial crystals.

† The sense of rotation is not reversed on inverting the plate.

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brought into coincidence with the other). For example, Group 17 has no planes of symmetry, but the forms are not enantiomorphs and circular polarization does not occur.

The classes in which circular polarization is possible are: TETRAGONAL SYSTEM. Class 9, to which no crystals have yet been referred. Class 10, circular polarization is not proved in any crystal of this class. Class 12, examples: strychnine sulphate, guanadin carbonate, diacetylphenol-thalein. HEXAGONAL: (RHOMBOHEDRAL DIVISION). Class 16, example: sodium periodate, $Na\ IO_4 . 3H_2O$. Class 18, examples: quartz, cinnabar, matico camphor $C_{12}H_{20}O$, tartrates of rubidium and caesium, subsulphates of lead, potassium, calcium and strontium; (HEXAGONAL DIVISION). Class 23, example: potassium-lithium sulphate, $K\ Li\ SO_4$. Class 24, circular polarization is not proved in any crystal of this class.

The direction of rotation corresponds to the right and left of the enantiomorphs.* With one or two exceptions, *e. g.*, sulphate of strychnine, circular polarization is destroyed by dissolving, fusing or vaporizing the crystal. Certain substances, however, showing in crystalline condition no power to rotate the plane of polarization show it in solution or in vapor, and are called optically active. These substances when in crystals are enantiomorphic right or left as the solution is right-handed or left-handed. If acids are optically active their salts usually are so.†

WITH PARALLEL MONOCHROMATIC LIGHT AND CROSSED NICOLS.

In sections normal to the Optic Axis the field will be illuminated, though only feebly in thin sections, and will only become dark when the analyzer has been turned an amount equal to the rotation

$$la = l\frac{\pi}{\lambda}(n'' - n').$$

That is, an amount increasing with the thickness and double re-

* Herschel in *Trans. Cambridge Soc.* I, 43, showed that circular polarization in quartz was apparently produced by the same cause which determined the position of the so-called plagihedral faces, for a plate of quartz cut perpendicular to the vertical axis of a crystal in which the left plagihedral faces occur will turn the plane of polarization of the incident ray to the left and a similar plate from a crystal showing the right plagihedral faces will turn this plane to the right.

† See Pasteur's lectures before Société chimique de Paris 1860, published as No. 28, Ostwald's *Klassiker der Exacten Wissenschaften. Ueber die Asymmetrie.* Leipzig, 1891.

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fraction in the direction of the optic axis and decreasing with the wave-length. Approximately

$$a = \frac{A}{\lambda^2} + \frac{B}{\lambda^4} + \text{etc.}$$

In all other sections there is extinction every 90° and brightest illumination in the diagonal positions. Extinction also takes place for $\frac{\Delta}{\lambda} = 1, 2, 3$, etc., as described p. 139.

WITH PARALLEL WHITE LIGHT AND CROSSED NICOLS.

In sections normal to the optic axis, since the rotation increases as the wave-length decreases, the different colors will be dispersed and emerge vibrating in different planes. As the analyzer is turned its plane of vibration will be successively at right angles to the planes of vibration of the different colors. That is, at any time only one color can be shut out completely and the rest in varying degree. The color with vibrations most nearly parallel to the vibration planes of the analyzer will be least shut out and will determine the predominating tint in the color seen.

In all other sections there will be extinction every 90° and greatest brightness in diagonal positions and the color tint due to interference as described p. 141.

WITH CONVERGENT LIGHT AND CROSSED NICOLS.

In sections normal to the optic axis, with monochromatic light, thin sections will show the dark cross the arms of which will always be parallel to the vibration planes of the nicols and somewhat indistinct near the centre. In thicker sections the bars will not reach the centre, Fig. 252, and no dark rings will form there, the first ring being some distance out, no matter how thick the section may be, beyond this there will appear the alternate dark and light rings with radii *nearly** as in last division.

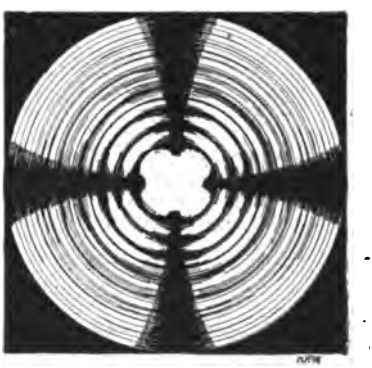

FIG. 252.

* Exact measurements show that the radii of the circles near the centre do not obey the law of common uniaxial crystals. J. C. McConnell, *Phil. Trans. Roy. Soc.* 1886 177, 299. 1887.

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In general the inner circle is bright except when the thickness for the light used gives $l\alpha = 180° \times n$, in which $n = 1, 2, 3$, etc., when it is black. With white light the central circle has the color tint which is obtained over the entire field when parallel light is used. On turning the analyzer each ring is decomposed into four arcs, which widen when the direction is that proper to the section and narrow when it is the opposite.

In sections oblique to the axis essentially as described p. 144.

In sections parallel to the optic axis essentially the hyperbolic curves of Fig. 243.

Determination of Optical Characters.

Most of the determinations are exactly as described under the preceding division. References may therefore be made as follows; *Direct determination of principal indices*, p. 131; *Extinction directions*, p. 145; *Faster and slower ray*, p. 146; *Retardation*, p. 146: *Strength of double refraction*, p. 147.

DETERMINATION OF DIRECTION OF ROTATION OF PLANE OF VIBRATION.

In a section normal to the optic axis and with crossed nicols:

(a) *By the widening of the arcs* when the analyzer is turned, in the direction of rotation.

(b) *A quarter undulation mica plate* inserted diagonally above

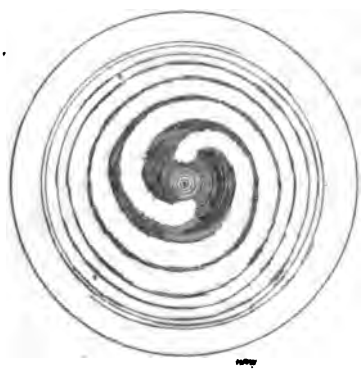

FIG. 253.

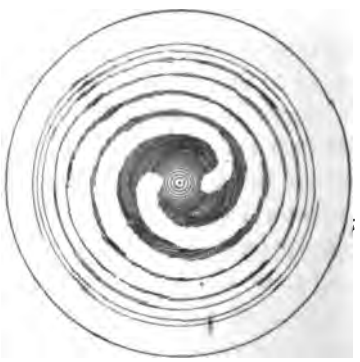

FIG. 254.

the plate converts the rings and cross into two interwound spirals, which start near the centre and wind in the direction of rotation.*

* A plate of left and another of right-handed substance give a fourfold spiral in which the direction of winding conforms to the lower plate.

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Fig. 253, Right; Fig. 254, Left. If the mica is placed below the plate the spirals are reversed.

(c) *The direction in which it is necessary to turn the analyzer* to change the tint of passage (see below) into red is the direction of rotation.

DETERMINATION OF ANGLE OF ROTATION OF PLANE OF VIBRATION.

In a section normal to the optic axis and with crossed nicols:

(a) *With monochromatic light* the rotation of the analyzer necessary to produce darkness is $l\alpha$.

(b) *With white light and Tint of Passage or Sensitive Tint.* When the analyzer is at right angles to the brilliantly coloring yellow green, for which $\lambda = 550\,\mu\mu$ in air, the remaining colors unite to an easily recognized grayish violet, called the tint of passage or sensitive tint, because the slightest further rotation in the one direction gives red and in the other blue. Starting with the polarizer and analyzer parallel the angle turned by the analyzer to produce the tint is $l\alpha$ for $\lambda = 550\,\mu\mu$ (middle yellow). Fig. 255 shows the rotations produced by a quartz plate of 3.75 mm. thickness. With parallel nicols the vibration plane of yellow is then at right angles to PS the vibration plane of the analyzer that is yellow is extinguished and the *tint of passage* results. With crossed nicols the tint of passage results when the vibration plane for yellow is PS, that is, for a rotation of 180° or a thickness of 7.50 mm.

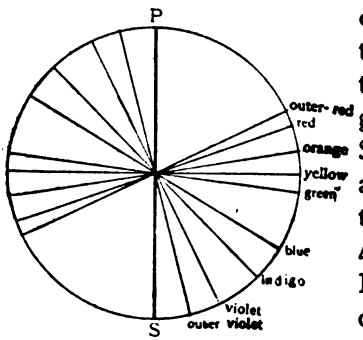

FIG. 255.

(c) *With white light and spectrum.*

The light polarized in P, Fig. 256, passes through the substance S, the collimator C, the analyzer A and through a slit and is decomposed by the prism R and viewed by the telescope T. As the analyzer is turned a dark line corresponding to the extinguished ray will move along the spectrum and the angles corresponding to the rotations (from crossed position) which bring this line into coincidence with the Frauenhöfer lines will correspond to $l\alpha$ for the corresponding values of λ.

If a quartz plate is placed at O, the light passes through the quartz, analyzer, slit and decomposing prism and yields a spectrum

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with a dark line. The analyzer is turned until the dark line coin-

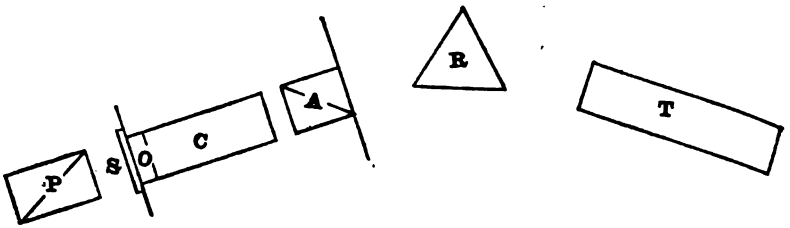

FIG. 256.

cides with a Frauenhöfer line; then the substance is introduced and the rotation necessary to bring the two lines again into coincidence is the value of la for that color.

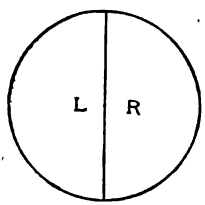

FIG. 257.

If a biquartz,* Fig. 257, of 7.50 mm. thickness be used, with crossed nicols, or one of 3.75 mm. with parallel nicols, a black line will appear for yellow ($\lambda = 550\,\mu\mu$), which for slight rotations of the analyzer will move into the blue or the red. With the introduction of the substance at S the black line is disturbed and the rotation necessary to re-establish it is the value of la for yellow.

ABSORPTION AND PLEOCHROISM.

In uniaxial crystals with monochromatic light the two rays corresponding to any direction of transmission are in general absorbed at a different rate. The faster ray may be either more absorbed or less absorbed than the slower, the absorption of the ordinary ray being independent of the direction of transmission, while that of the extraordinary varies with the inclination to the optic axis, but is constant for the same angle and differs most from that of the ordinary for transmission normal to the optic axis.

With white light the color seen in any direction will be due to a combination of the ordinary and extraordinary rays, and this combination will give different tints in different directions.

Usually the two rays are viewed separately by means of a polarizing microscope with the analyzer out. The color varies as the

*Two semicircular basal plates of right and left quartz, of equal thickness (Biot's 3.75 mm., Soleil's 7.50 mm.) and with their twinning plane either parallel or at right angles to the vibration plane of the polarizer.

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stage is turned and the maximum color differences are obtained when the extinction directions coincide with the vibration plane of the polarizer (shorter diagonal).

In sections normal to the optic axis the color is constant for all positions of the stage.

In sections parallel to the optic axis. If the extinction direction parallel to the optic axis is placed first parallel then at right angles to the short diagonal there will be seen first the extraordinary, second the ordinary.

In all other sections the extraordinary will be found to approach the constant tint of the ordinary as the sections become more nearly perpendicular to the optic axis.

The colors of ordinary and extraordinary may be contrasted side by side by means of a "dichroscope" consisting, Fig. 258, of

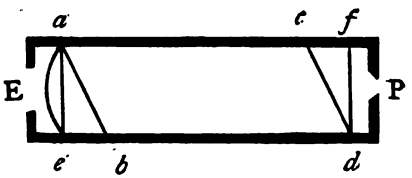

FIG. 258.

a rhomb of calcite in which *ab* and *cd* are the short diagonals of opposite faces. To these faces glass wedges *aeb*, *dfc* are cemented and the whole encased. The section is placed at *P* and the light from the substance passes through a rectangular orifice, a double image of which is seen by the eye at *E*.

When the planes of vibration of the section and the calcite coincide the two rays originated in the section will have the maximum color difference of the section.

If the plate is turned around the axis of the dichroscope each ray from the crystal is decomposed in the calcite and contributes a portion of its intensity to each of the two images and at 45° each will contribute half of its brightness to each image; that is, the the two images will then be alike in color and brightness.

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CHAPTER X.

THE OPTICALLY BIAXIAL CRYSTALS.

In any orthorhombic, monoclinic or triclinic crystal the ray surface for light of any definite wave-length is symmetrical to three planes at right angles to each other which intersect in the vibration directions of the fastest and slowest rays, the third intersection being the vibration direction of a ray of some intermediate velocity.

The planes of symmetry are called *Optical principal sections* and their intersections are called *Principal vibration directions.** No diameter is an axis of isotropy, that is a direction about which the crystals are optically equivalent, but in two directions there is single refraction and these directions from analogy with the uniaxial are called the "Optic axes" *for light of that wave-length.*

As in the uniaxial crystals the relative values of the *principal indices of refraction*, that is, the indices of the rays with the principal vibration direction, change with the wave-length. But as a consequence the directions of the optic axes change also, the amount of change or so called "dispersion" varying from a few minutes to over forty degrees. That is, the optic axes in this group of crystals are not fixed in position as in the uniaxial.

With decreasing geometric symmetry not even the optical principal sections or principal vibration directions remain fixed in direction, but alter with the change of light. Upon this so-called "Dispersion of the Bisectrices" are based optical distinctions between the systems.

In *Orthorhombic Crystals* the geometric axes are always principal vibration directions and the axial planes are optical principal sections for all colors.

In Monoclinic Crystals the ortho axis *b* is always a principal vibration direction and the clinopinacoid 010 is an optical principal section for all colors, lie in 010 but, the other two principal vibration directions vary in position with the wave-length.

In Triclinic Crystals there are no principal vibration directions or principal sections which are constant for all colors.

*Often called axes of elasticity.

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THE OPTICAL INDICATRIX.

The inductive method by which the present conception of a biaxial ray surface has been reached may be briefly outlined as follows:

It was shown by Huyghens that the ray surface of calcite was a double surface composed of a sphere and an ellipsoid of revolution, and the ray surfaces of other tetragonal and hexagonal substances were found to be similar and symmetrical always to the crystallographic planes of symmetry. It was later shown that from an ellipsoid of revolution all the relations between direction of transmission, velocity and vibration direction could be deduced.

By analogy it was conceived that for any less symmetrical crystal some correspondingly less symmetrical figure or Optical Indicatrix existed from which these relations and the shape of the ray surface could be geometrically determined. Experiment has proved this to be true, and that for orthorhombic, monoclinic and triclinic crystals the optical indicatrix is an ellipsoid the three rectangular axes of which are in length equal to the so-called principal indices of refraction.

Let $\alpha < \beta < \gamma$ be these principal indices of refraction and $\mathfrak{a}$, $\mathfrak{b}$ and $\mathfrak{c}$ the *directions* of vibration of the corresponding rays, that is, of the rays with greatest, intermediate and least velocity of transmission. Upon the directions $\mathfrak{a}$, $\mathfrak{b}$, $\mathfrak{c}$ lay off $O\mathfrak{a} = \alpha$, $O\mathfrak{b} = \beta$, and $O\mathfrak{c} = \gamma$ and upon these as axes construct an ellipsoid that is the Optical Indicatrix, Fig. 259. Then, by analogy with the uniaxial, p. 130, for any diameter considered as a direction of transmission there are two points of the surface the normals from which are also normal to that diameter. *These normals are at once the directions of vibration and the reciprocals of the velocities of the rays transmitted in the direction of the diameter.*

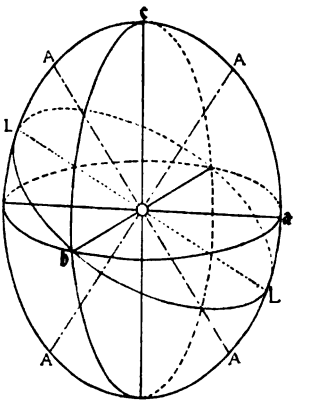

FIG. 259.

RAY SURFACE.

The shape of the ray surface may be judged from the shape of the optical principal sections $\mathfrak{ab}$, $\mathfrak{cb}$ and $\mathfrak{ac}$.

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Optical Principal Section . For the direction aO, Fig. 259, the two normals are bO and cO corresponding to velocities $\frac{I}{\beta}$ and $\frac{I}{\gamma}$; for the direction bO the normals are aO and cO, corresponding to velocities $\frac{I}{\alpha}$ and $\frac{I}{\gamma}$, for any other direction one normal is cO, the other a line in ab, found as described on p. 130 and varying in length between aO and bO, according to the direction of the ray, like the radius vectors of an ellipse. Hence for any direction of transmission one ray vibrates in some direction in ab, but is transmitted with a velocity varying like the radius vectors of an ellipse between $\frac{I}{\alpha}$ in the direction b to $\frac{I}{\gamma}$ in the direction a, Fig. 260, and corresponds to an extraordinary ray.

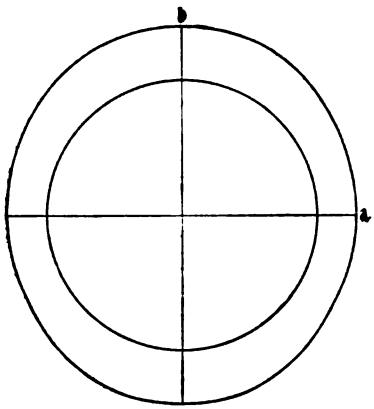

FIG. 260.

The other ray for any direction vibrates in the direction of c, normal to ab and is transmitted with constant velocity $\frac{I}{\gamma}$. It corresponds, therefore, to an ordinary ray. Hence for ab the sections of the two shells are as in Fig. 260.

Optical Principal Section, cb. In precisely the same manner it is shown that for any direction of transmission in the plane cb one ray is extraordinary in that its vibration direction is always b and its velocity varies between $\frac{I}{\gamma}$, in the direction b, to $\frac{I}{\beta}$ in the direction c; whereas the other ray is ordinary with a constant vibration direction a normal to cb and a constant transmission velocity $\frac{I}{\alpha}$. That is for cb the sections of the two shells are as in Fig. 261.

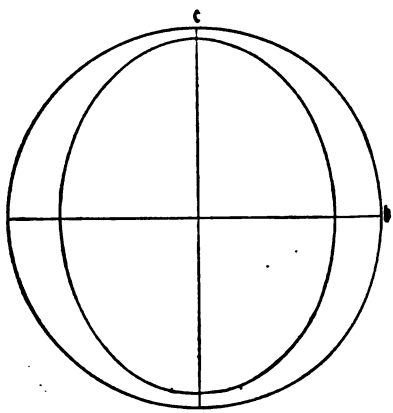

FIG. 261.

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Optical Principal Section ac *or Plane of the Optic Axes.* In this case for any direction of transmission one ray is extraordinary with its vibration direction in ac and velocity varied between $\frac{1}{\gamma}$ in the direction a and $\frac{1}{a}$ in the direction c, while for the ordinary ray the constant vibration direction is b and the constant velocity $\frac{1}{\beta}$. That is, in this section of the two shells, there must be four symmetrically placed points of intersection *E*, as shown in Fig. 262. Each principal section then consists of an ellipse and a circle. The entire surface may be generated as follows.

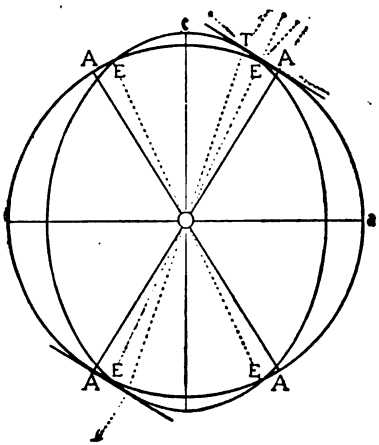

FIG. 262.

Revolve the section ac about one of its axes a, the curves of the section touching always those in the section ab and altering according to a definite law until after 90° rotation they coincide with the curves of the section cb.

OPTIC AXES.*

In Section ac of the indicatrix, Fig. 259, there must be a radius vector *OL* equal β, for these vary between a and γ. Similarly *OL'* (not shown) symmetrically opposite *OL* will equal β. The sections of the indicatrix through *OL Ob* or *OL' Ob* must be circles.

In section ac of the ray surface, Fig. 262, near but not at the points *E*, common tangent planes can be drawn to each shell.

The directions normal to these circular sections in the indicatrix and to the common tangent planes in the ray surface are the so-called optic axes *AA* of Fig. 262.

A circular section of the indicatrix is the common ray front of all the diameters determined, p. 271, by the normals to the indicatrix from each point of the circle. Of these normals only one, *Ob*, is *in* the circle, hence only one diameter is normal to the circle (the optic

* The directions *EE* are variously called Ray Axes, Secondary Axes, and Biradials and are simply directions of equal ray velocity, the ray, however, corresponding to an infinite number of planes tangent at *E*, the normals to which diverge and form a cone (outer conical refraction).

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axis), while the others starting from O diverge and form a cone. Furthermore since the normals are all in different directions the rays, transmitted in the directions of the diameters; have all directions of vibration. The same facts are evident from Fig. 262; the common tangent plane caps the conical depression at R. From each point of the circle of contact the lines to O represent rays with a common ray front and of which the front normal is the optic axis. That is, each optic axis is the front normal for a diverging cone of rays (inner conical refraction) which on emergence are parallel to this front normal but each of which has a different direction of vibration.

The velocity in the direction of an optic axis is evidently $\frac{1}{Ob} = \frac{1}{\beta}$.

Positive and Negative Ray Surfaces.

In the plane of the optic axes a and c bisect the angles between these axes. If the acute bisectrix is c, ($Bx_a = c$), that is, if c bisects the acute angle between the optic axes the ray surface is said to be *positive*.

If the acute bisectrix is a, ($Bx_a = a$), that is, if a is the acute bisectrix and c the obtuse, the ray surface is said to be negative. This conforms strictly to the usage in the uniaxial which is a special case of biaxial with the angle between the optic axes zero, that is with one optic axis in the direction c.

Refraction in Biaxial Crystals.

In general, following the Huyghens construction, p. 115, the new ray fronts through the point E, Fig. 208, are tangent to the shells in points which do not lie in the plane of incidence, that is, both rays are bent out of the plane or are *extraordinary*. With normal incidence this is still true. Let $SURT$, Fig. 263, be the section of the indicatrix normal to the ray. The planes ROf and TOf through the axes of the ellipse and the front normal contain the two rays Oe and Ot at right angles to the surface normals RE and UN. These normals are the vibration direction of the rays and are not

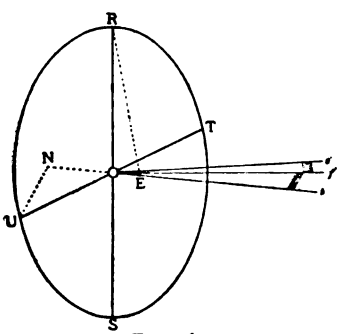

Fig. 263.

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at right angles to each other, though on emergence both rays retake the direction *Of* with vibrations at right angles and a phase difference.

Because *SURT* is normal to the incident ray it is parallel to the plate, hence the extinction directions in the plate are *OR* and *OU* the projections of the vibration directions.

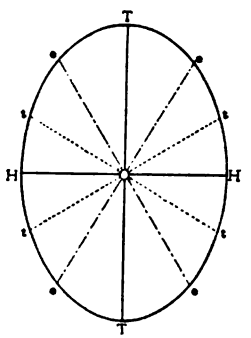

FIG. 264.

If the plane of incidence be a principal section then the points of tangency of the new ray fronts will be in the plane. One will for all directions show a constant refraction index and may be called the ordinary.

WITH PARALLEL MONOCHROMATIC LIGHT AND CROSSED NICOLS.

In sections normal to an optic axis the field will maintain a uniform brightness during rotation of the stage, because p. 274, in the emerging cylinder of rays developed by inner conical refraction each ray vibrates in a different plane.

In all other sections the field is dark every 90° and is illuminated for all other positions and most brilliantly in the diagonal positions. The field is also dark throughout an entire revolution for $\frac{\Delta}{\gamma} = 1, 2, 3$, etc., p. 139, and brightest for $\frac{\Delta}{\gamma} = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, etc., in all conforming to similar uniaxial sections.

Relation between Extinction Directions and Optic Axes. As just explained, the extinction directions are the diameters of that central section of the indicatrix which is parallel to the plate. The two circular sections must intersect any central section in *equal* diameters *tt* which from the nature of an ellipse must be symmetrical to the axis of the ellipse, that is, to the extinction directions.

If planes be passed through the plate normal and each optic axis their traces *ee* will be at 90° to those of the circular sections, hence also symmetrical to the extinction directions. *That is, the extinction directions must* bisect the angle between the traces of the two planes, each through the plate normal and an optic axis.*

WITH PARALLEL WHITE LIGHT AND CROSSED NICOLS.

In sections normal to an optic axis for light of one color there is

* Upon this principal and after a device by Prof. Groth, Böhm and Wiedemann, of Munich, construct a model for graphic determination of extinction directions.

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constant illumination throughout rotation because of internal conical refraction p. 274; the optic axes for other colors are, however, more or less oblique to the section and double refraction takes place, and as the resulting vibration directions are somewhat differently oriented for each color, color tints result somewhat as in circular polarization.

In all other sections. If there is no marked dispersion of the principal vibration directions there will be approximately perfect extinction every 90° and interference colors as in the uniaxial, but with marked dispersion the vibration directions in any plate diverge for the different colors and the plate can never be perfectly dark and moreover in any position the interference colors due to phase difference are modified by color tints due to the partial or complete extinction of certain colors.

WITH CONVERGENT MONOCHROMATIC LIGHT AND CROSSED NICOLS.

In sections normal to a *or* c there will be darkness whenever the vibration planes of the emerging rays coincide with those of the nicols and whenever $\frac{\Delta}{\lambda}$ is a whole number; see p. 139. The points of emergency of the optic axis will therefore be dark, since $\frac{\Delta}{\lambda} = 0$, and the points corresponding to $\frac{\Delta}{\lambda} = 1$ will together form a ring around each axis and similarly for values of 2, 3, 4, etc., until the pair corresponding most nearly to the value $\frac{\Delta}{\lambda}$ for the centre of the field* unite at or near the centre to a cross loop or figure eight around both axes and subsequent rings form lemniscates around this as in Fig. 265. If $\frac{\Gamma}{\lambda}$ for the centre is less than unity even the first ring must surround both axes, giving them a figure more

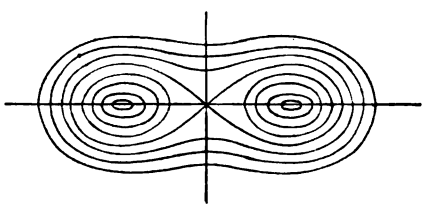

FIG. 265.

* For the rays transmitted normally at the center of the field $\frac{\Delta}{\lambda} = \frac{t}{\lambda}(n_1 - n)$. If the direction of transmission is c then $n_1 - n = \gamma - \beta$ and if direction is a then $n_1 - n = \beta - \alpha$. In either case $\frac{\Delta}{\lambda}$ is known and determines the number of rings between the axes and the centre.

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similar to that of a uniaxial crystal. As all parts of lemniscates are independent of positions of planes of vibration, there will be no change from rotation of the stage.

When the stage is rotated so that principal sections are parallel to the vibration planes of the nicols all the rays transmitted in those sections (therefore vibrating in or at right angles to those sections) will be extinguished and there will be a sharp dark band joining the poles and another somewhat thicker dark band at right angles to the first and midway between the poles. These are often called brushes. For any other position of the stage the vibrations of some other rays are parallel to those of the nicols, and these are always so distributed that the resultant dark spots form the branches of an hyperbola through each of the axes. At the diagonal position the effect is as in Fig. 266.

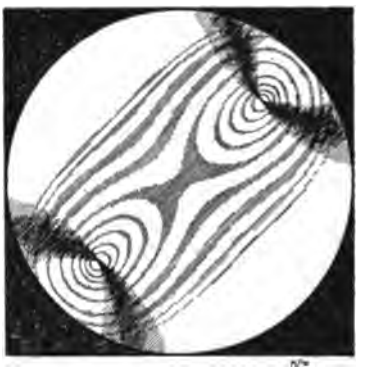

FIG. 266.

As the stage is rotated the straight bars appear to dissolve into the hyperbola, the branches of which appear to rotate in the opposite direction to the stage, the convex side always toward the other axis. If $\frac{\Delta}{\lambda}$ is nowhere equal to 1 there will be no dark rings, but the hyperbola will behave as usual. Because the two principal sections are planes of symmetry the curves and brushes are at all times symmetrical to the traces of the sections.

In sections normal to b the dark curves due to $\frac{\Delta}{\lambda} = 1, 2, 3$, etc., are hyperbolæ similar to those shown, Fig. 243. No brushes are visible.

In sections normal to an optic axis there will be the same formation of dark rays corresponding to whole numbers for $\frac{\Delta}{\lambda}$, the curves, however, will be more nearly circles, Fig. 267. There will be a straight black bar bisecting the curves whenever the trace of the plane of the optic axes coincides with the vibration direction of either nicol, and for all other angles of rotation there will be

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one arm of an hyperbola through the axis, Fig. 268, the convex side towards the other axis. This arm will rotate in the opposite direction to the stage.

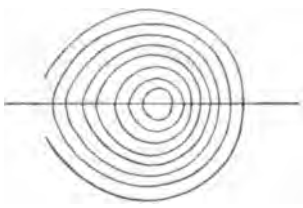

FIG. 267.

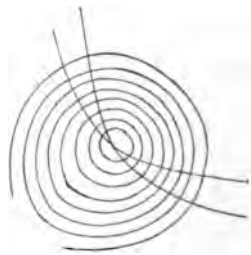

FIG. 268.

WITH CONVERGENT WHITE LIGHT AND CROSSED NICOLS.

In sections normal to the acute bisectrix Because of the dispersion of the optic axes described, p. 270, the centres of the ring systems are not the same for the different colors. If there is also a dispersion of the bisectrices the section can only be exactly normal to the bisectrix for one color. These facts, added to the general one that for different colors the greater the wave-length the greater the distance apart of the rings, render it possible in white light to determine the crystalline system by the distribution of the colors, thus obtaining Divisions V, VI and VII.

V. ORTHORHOMBIC CRYSTALS.

The color distribution must be symmetrical to the line joining the optic axes and to the line through the centre at right angles thereto, because these are the traces of the principal sections common to the ray surfaces of all the colors. Assuming that the same principal section is the axial plane for all colors there may be two cases: 1°. The axes for the longer wave-lengths may be most dispersed, that is, the angle between the optic axes for red greater than that for violet, or $\rho > \upsilon$. 2°. The axes for the shorter wave-lengths may be most dispersed, that is, the angle between the optic axes for red less than that for violet, or $\rho < \upsilon$.

Figure 269 illustrates the second class. In the interference figure for the diagonal position the hyperbolae will pass through the axial points for each color and in each that color will be extinguished, giving, if the dispersion is great, a series of colored bands ranging from red (white minus violet and part of blue)

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through the violet axes; to blue or violet (white minus red and part of yellow) through the red axes. Generally the intermediate colors overlap, producing a dark band, except on the outer fringes. That is, the colors* fringing the hyperbola are in inverse position to the axial points.

Similarly, if the full line circles represent the first extinction ring for violet and the dotted those for red, then as we pass from the centre red is first extinguished and the violet tint shown.

For $\rho < \upsilon$ the red is further from the centre than the blue. For $\rho > \upsilon$ the red is nearer the centre than the blue. Or in general, the color with the larger angle is nearer the centre of the field.

If the axial plane is not the same for all colors, that is, if $\mathfrak{b}$ for certain colors becomes $\mathfrak{a}$ or $\mathfrak{c}$ for others, then the interference figures will be turned 90° with respect to each other and, if superposed in white light, will give a complex figure as in brookite.

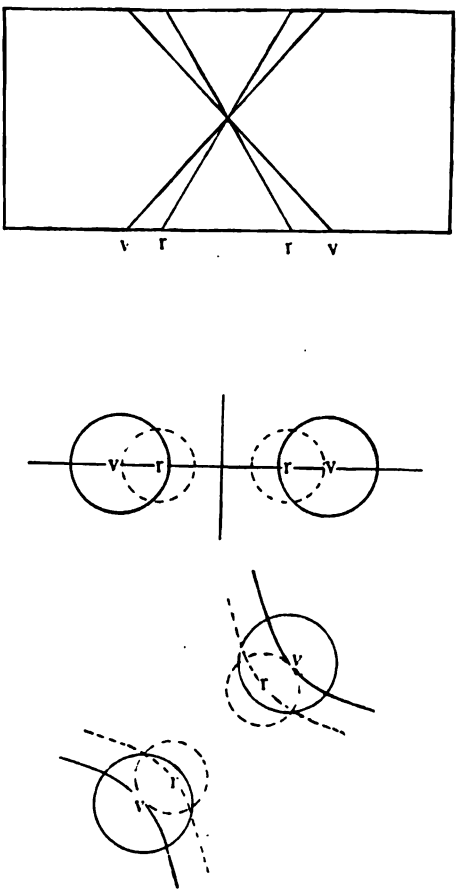

FIG. 269.

VI. MONOCLINIC CRYSTALS.

There must also be considered the dispersion of the bisectrices. Three general cases have been distinguished, in all of which 010 is a principal section and the ortho axis b a principal vibration direction.

* The dotted curves should be colored blue; the full line curves red, in Figs. 269–272.

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(a) *Inclined Dispersion.* The optic axes for all the colors lie in the plane 010 and the ortho axis b is $\mathfrak{b}$, the intermediate principal vibration direction, but $\mathfrak{a}$ and $\mathfrak{c}$ vary in position in the plane 010. Evidently the color distribution will be symmetrical to 010.

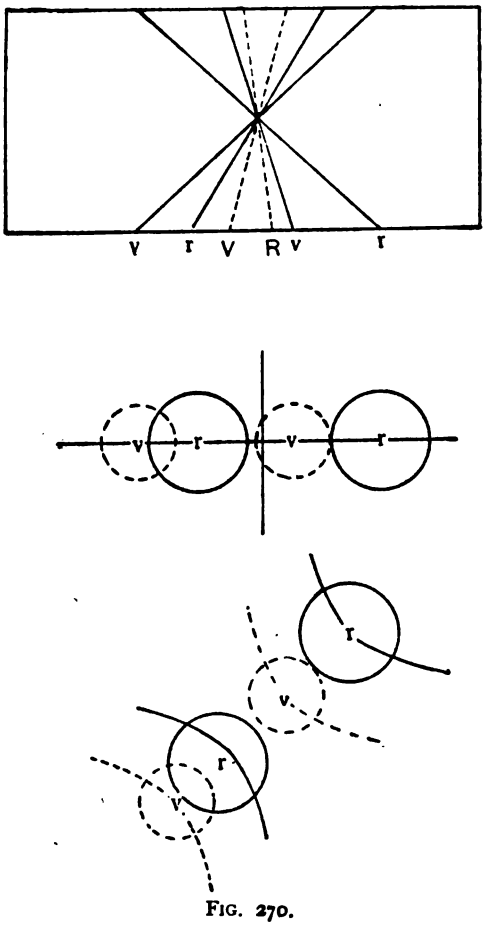

FIG. 270.

Let Fig. 270 represent the plane 010 in a section cut normal to the acute bisectrix for yellow light. The acute bisectrices for red and violet will be oblique to this section as represented. Assume $\rho < \upsilon$ and construct the interference hyperbolæ and first ring for the diagonal positions. Four things are at once noticed:

1°. The color-distribution and shape are symmetrical to the trace of 010 and to this line* only.

2°. The combination color rings around the axes due to overlapping of rings for the different colors are very different, the one relatively small, circular and intense, the other larger, oval and relatively dull. The sequence of colors may be the same or reversed.

3°. The smaller ring is further from the centre of the field.

4°. One hyperbola band is much broader than the other.

(b) *Horizontal Dispersion.* If the ortho axis b is the acute bisectrix (either $\mathfrak{a}$ or $\mathfrak{c}$ as the crystal is + or −) then the planes of the optic axes must for all colors pass through it and be normal to the plane 010. In a section cut normal to the acute bisectrix for yellow light let V and R, Fig. 271, represent the axial planes for violet

* Line connecting the axial points.

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and red, *rr* the optic axes for red, *vv* those for violet. The plane 010 (not shown) is normal to all the axial planes.

In the interference figure it is evident that the color-distribution and shape of the lemniscates are symmetrical to the trace* of 010 but not to any other line. Hence, for normal position the hori-

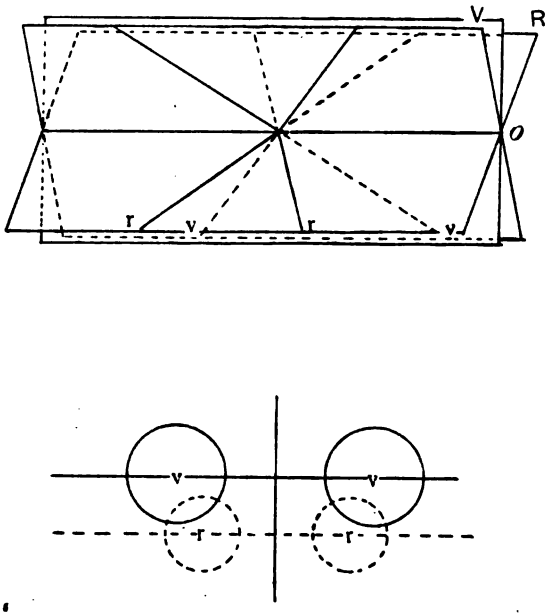

FIG. 271.

zontal dark bar will be centrally black from overlapping colors, but on the edges will be red and violet or blue.

(c) *Crossed Dispersion.* If the ortho axis *b* is the acute bisectrix (either c or a as the crystal is positive or negative) then will the section normal to the acute bisectrix for one color be normal for all and will itself be parallel to 010. The axial planes for all colors will pass through *b*, and as *b* corresponds to a or c it is an axis of binary symmetry, hence the color-distribution and shape of the lemiscates must be such that any straight line through the centre of the field passes in each direction through similar points. That is, diagonally opposite parts of the field are similar. In Fig. 272 *V* and *R* are the axial planes for violet and red.

It will be noticed that the chief reliance throughout is upon the

* Normal at centre to line joining the axes.

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colors that fringe the horizontal brush or the hyperbola, and that this is in every case the other end of the spectrum to the color of the light producing it.

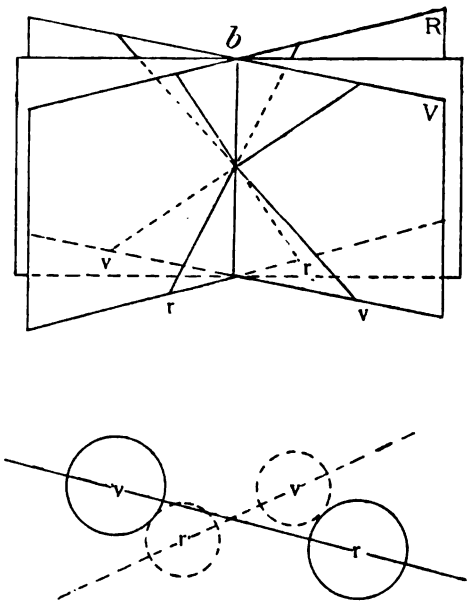

FIG 272.

VII. TRICLINIC CRYSTALS.

With triclinic crystals there is no symmetry at all in the arrangement of the colors in the interference figure from white light. Two or more varieties of dispersion may occur at once.

Plates normal to the obtuse bisectrix show similar phenomena, though frequently it is impossible to obtain the interference figures within the field. The color-distribution is naturally changed as the dispersion of axes is in the opposite direction.

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TESTS OF FULL-SIZED CAST-IRON COLUMNS.

By WM. H. BURR.

Although cast-iron columns are among the oldest of metallic structural members it, is a little singular that they have been tested to failure only within the last ten years and in small numbers. This is the more serious for the reason that to the non-technical mind the short brittle fracture of cast iron indicates hardness and strength rather than unreliability and weakness.

While it has been well known among civil engineers for many years that the strains in cast-iron for given loads per square inch may frequently be and usually are nearly twice as great as for wrought-iron, there has arisen the thoroughly erroneous idea that the ultimate resistance of cast-iron columns could in some way be shown to be proportional to, or a function of, the ultimate compressive resistance of cast-iron in short blocks. That idea found apparent confirmation in the experiments of Hodgkinson about sixty years ago. He experimented on columns of small cross-sections (solid and hollow), not over 4 inches in diameter, and with lengths not exceeding ten feet. Columns of such diameters, particularly if cast for experimental purposes, will obviously be far freer from internal defects so common to full-sized cast-iron members than the columns used in structures. It has long since come to be one of the cardinal principles of civil engineering practice that the ultimate resistances of full sized members of all descriptions can only be determined with sufficient accuracy for the best practice by testing such members to failure.

The data afforded by the results of Hodgkinson's test of these small model columns, together with the results of tests of short cast-iron blocks, have been the basis of the formulæ and tables used in the design of cast-iron columns in nearly all structural practice to the present time. That practice has chiefly represented building construction for the reason that civil engineers have excluded cast-iron columns from bridge structures for more than twenty years. They have realized that the empirical basis of the formulæ in use was dangerously insufficient, and the early experiences with column fractures in railroad bridges constituted a clear and conclusive demonstration of the marked unfitness of cast-iron for such purposes. The continued use of cast-iron columns in

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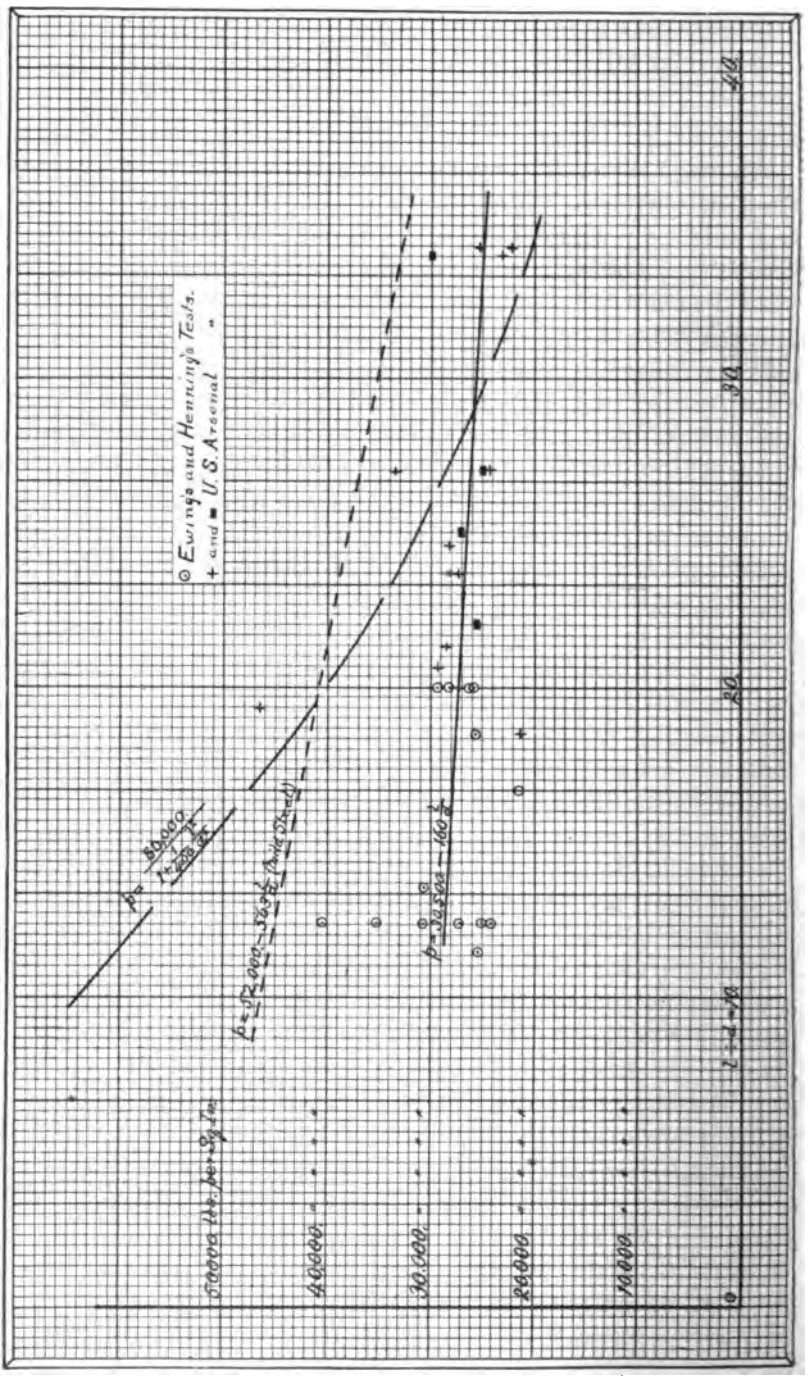

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buildings, however, renders imperative the testing of full-sized members of that class to destruction in order to determine rational and safe working stresses.

It was not until 1888–1889 that a series of the needed tests was begun at the request of Prof. Lanza in the large Emery machine at the United States Arsenal at Watertown, Mass. Those tests have been followed by others at Phœnixville, Pa., made under the auspices of the Department of Buildings of New York City in 1896 and 1897. Although the entire series, including both the tests at Watertown and Phœnixville, do not cover the variety of sectional forms and range of ratio of length to diameter that could be desired, the results are sufficiently extended to show closely what may be considered the proper ultimate values for hollow, round cast-iron columns of full size.

TABLE I.

No.	Length in inches.	Diameter in inches.				Area of section in square inches.	Length over Exterior Diameter.	Ultimate Resistance in pounds per square inch.
		Large end.		Small end.				
		Ext.	Int.	Ext.	Int.			
1	190.25	15	13			43.98	12.7	30,830
2	"	15	12.75			49.03	12.7	27,126
3	"	15	12.75			49.03	12.7	24,434
4	"	15⅛	12.75			49.48	12.7	25,182
5	"	15	12.66			50.91	12.7	35,435
6	"	15	12.63			51.52	12.7	40,411*
7	160	8	6			21.99	20	29,604
8	160	8	5.91			22.87	20	28,229
9	120	6.06	3.78			17.64	20	25,805
10	120	6.09	3.96			17.37	20	26,205
11	147.75	8	6.5			17.08	18.5	25,973
12	150	9	7			25.14	16.7	21,183
13	162	12	10			34.55	13.5	30,813
14	159.75	14	12			40.84	11.4	25,400
15	169	5	4.54			3.5	34	29,854
16	157	7.17	4.83			21.8	22	25,470
17	157	6.35	3.9			17.28	25	27,210
18	156	5.8	4.03			13.22	27	25,100
19	142.6	7.68	5.52	5.94	4.3	17.49	26.7	29,310
20	146.8	8.01	5.58	5.9	4.35	18.65	21.3	28,520
21	150	6.17	4.85	5.09	3.48	12.08	27	33,500
22	145.5	6	4.35	4.74	2.73	12.81	37.1	24,620
23	133.6	6.02	4.36	4.84	2.88	12.87	24.6	28,060
24	129.3	6.03	4.35	4 87	2.95	12.87	23.7	27,350
25	127.6	7.47	5.97	5.72	4.62	12.13	19.3	46,660
26	118.5	3.98	1.96	2.97	1.49	7.16	34.1	23,090
27	119	3.98	1.96	2.98	1.47	7.17	34.3	22,040
28	118	3.97	1.95	2.99	1.39	7.32	34.2	25,060
29	84.6	4.88	3.03	4.27	2.08	11.25	18.5	31,190

* Not broken.

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Table I shows the result of all these tests, while the Plate exhibits the same results graphically. The tests, Nos. 1 to 10 inclusive, were made at Phœnixville in December, 1897, and Nos. 11 to 14 inclusive in 1896; the former group under the immediate direction of Mr. W. W. Ewing, and the latter under the immediate direction of Mr. Gus C. Henning. The results shown for tests 15 to 18 inclusive were taken from H. R. Ex. Doc. No. 45 Fiftieth Congress, 2nd Session, but those for Nos. 19 to 29 inclusive are either taken or digested from H. R. Ex. Doc. No. 16 Fiftieth Congress, 1st Session, being portions of reports of tests of metals and other materials at the United States Arsenal, Watertown, Mass.

As Table I shows the columns, Nos. 19 to 29 inclusive, were slightly conical, although probably not enough so to affect appreciably their resistances. The areas of section in square inches for these colums were taken at mid-distance between their ends. As the area of section varied considerably in some columns that operation may be a source of a little error in determining the ultimate resistance per square inch from the result of the tests, but if the error exists at all it must be very small. The mid-external diameter was also taken for these columns in determining the ratio of the length over the diameter shown in the Table and in the Plate.

As will be observed both in the Table and in the Plate, the ultimate resistances per square inch determined by the tests are quite variable, even for the same ratio of length over diameter. Indeed, in a number of cases they are quite erratic. In Nos. 1 to 6, for which the ratio of length over diameter was 12.7, the ultimate resistances vary from a little over 24,000 lbs. per square inch to over 40,000 lbs. per square inch with no failure at the latter value. Again, the ultimate resistance per square inch for No. 25, which shows a ratio of length over diameter of less than 20, is nearly 47,000 lbs. per square inch, which is excessively high as compared with other ultimate resistances with the same or less ratio of length over diameter. These erratic results are not surprising in view of the ordinary character of the metal. It should be remembered that the failures of these columns are frequently recorded with such "remarks" as the following: "Foundry dirt or honey-comb between inner and outer surfaces," "bad spots," "cinder pockets and blow holes near middle of column," "flaws and foundry dirt at point of break." In other words, it was no uncommon feature to observe that defects, flaws or blow holes or thin metal had determined the

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place of failure. There is considerable uncertainty in platting the results of tests affected by these abnormal conditions, but a more or less satisfactory law for the generality of cases may be determined from a graphical representation of the results, as shown on Plate I. On that Plate the ultimate resistances in pounds per square inch, as shown in Table I, have been platted as vertical ordinates, while the ratios of length over diameter given in the same Table are represented by the horizontal abscissas, all as clearly shown. The full straight line drawn in about a mean position among the results of the tests probably represents as near as any that can be found a reasonable law of variation of ultimate resistance with the ratio of length over diameter. It is evident that within the range of these experiments a straight line will represent the ultimate resistances fully as well as any curve, if not better, although the results for the lengths of thirty-four times the diameter begin to indicate a little curvature. The formula which represents this straight line, *i. e.*, which gives the ultimate resistance per square inch, is as follows:

$$p = 30{,}500 - 160\,\frac{l}{d} \qquad (1)$$

It is to be borne in mind that these columns were round and hollow, and that they were tested with flat ends in all cases. The ordinary formula, based upon Hodgkinson's tests, and frequently used in cast-iron column construction, and practically required by the Building Law of New York City, is as follows:

$$p = \frac{80{,}000}{1 + \frac{1}{1\,0\,0}\,\frac{l^2}{d^2}} \qquad (2)$$

The curve corresponding to this particular form of Tredgold's formula is also shown on the Plate. It will be seen that at the ratio of length over diameter of 10 to 12 (not an uncommon ratio) the ultimate, as given by this formula, is just about double that shown by actual test. In other words, if a safety factor of five were required, as is the case in the New York Building Law, the actual safety factor would be but 2½. At the upper limit of length over diameter permitted by the Building Law, viz: 20, the ultimate resistance given by the ordinary formula, Eq. 2, is about 1½ as great as it should be. In other words, if the safety factor

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were five by that formula the actual factor $l \div d = 20$ would be but a little over three. The curve represented by Eq. 2 is seen to cross the true curve at a ratio of length over diameter of about 29. A glance at the Plate will show how utterly erroneous and dangerous is the use of the usual formula for hollow round cast-iron columns; indeed, that formula is grossly wrong, both as to the law of variation and the values of ultimate resistance.

In view of the working resistances, which have been used in the design of cast-iron columns, it is no less interesting than important to compare the ultimate resistances per square inch of mild steel columns, as determined by actual tests, with the ultimate resistances of cast-iron columns, as shown by the tests under consideration. The broken line of short dashes represents the formula

$$p = 52{,}000 - 563\frac{l}{a} \quad - - - - - \quad (3)$$

determined by actual tests of mild steel angles made by Mr. James Christie at the Pencoyd Bridge Works, and which are well known among civil engineers. This line or formula shows that the ultimate resistances per square inch of mild steel columns are from 40 to 50% greater than the corresponding quantities for cast-iron, the same ratio of length over diameter being taken in each comparison.

When the erratic and unreliable character of cast-iron is considered, it is no material exaggeration to state that these tests show that the working resistance per square inch may probably be taken twice as great for mild steel columns as for cast-iron; indeed, this may be put as a reasonably accurate statement.

The series of tests of cast-iron columns represented in the Plate largely destroys confidence in the cast-iron column design of the past. The results of the tests constitute a revelation of a not very assuring character in reference to cast-iron columns now standing, and which may be loaded approximately up to specification amounts. They further show that, if cast-iron columns are designed with anything like a reasonable and real margin of safety, the amount of metal required dissipates any supposed economy over columns of mild steel. As a matter of fact, these results conclusively confirm what civil engineers have long known, that the use of cast-iron columns cannot be justified on any reasonable ground whatever.

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THE SCHOOL OF ARCHITECTURE IN ITS NEW QUARTERS.

By PROFESSOR WILLIAM R. WARE.

Since the last issue of the QUARTERLY the collections of the School of Architecture have been put in place, and it is now enjoying in full measure the advantages of its new home in Havemeyer Hall. The spaciousness of these quarters, which are clean, quiet and light, and the increased facilities which they give for the use of the material equipment of the School, much of which has until now been unavailable for want of room, have given a new zeal to students and instructors alike. The installation of the major part of these collections in the attic story was made possible by the same generous friend of the School who has so often supplied its needs. The collections themselves are already extensive and interesting, and bid fair to grow into a museum of exceptional value for the courses both in Building Construction and in the Decorative Arts. They comprise a number of models of framed buildings, roofs, floors and so forth, with full-sized details and specimens of building materials and appliances, hardware and iron work, and of different kinds of woods. Besides a quantity of modern American and English glass and tiling, there are fragments of mediæval glass work, some of which came from the original windows of the *Sainte Chapelle*, half a dozen Saracenic windows in glass and plaster from houses and mosques in Cairo, and a quantity of Moorish and Spanish tiles from a dismantled monastery in Seville. These collections are constantly increased by gift, the manufacturers of useful and of decorative work being equally helpful in contributing to these stores.

The Roman casts, ancient and modern, from fragments of temples and from the Villa Madama, presented by Mr. C. F. McKim in 1891, which were scattered about on the walls of various rooms in Forty-ninth Street, are now effectively exhibited in the eastern draughting-room. The larger pieces make a fine show in the Museum above. These comprise a cast, eight or ten feet long, from the frieze of the Temple of Antoninus and Faustina, a similar fragment from the Forum of Trajan, and the great alto-relievo of the *Suovetaurilia*, from the voting place in the Roman Forum.

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They are appropriately surmounted by a relief of a Roman eagle within a wreath, also from Trajan's Forum, and are flanked by casts of the two lions now in the Loggia dei Lanzi, at Florence, one of which is antique, the other a companion piece modelled by Flaminio Vacca. The glazed sashes in the ceiling of the corridor beneath have been removed, resembling the corridor to the atrium of a Pompeiian house, so that these things are partially discerned from below.

This corridor proves to be one of the most attractive as well as one of the most useful of places. It serves not only as a *Salle des Pas Perdus*, for walking and talking in intervals of leisure, but as a gallery in which are shown the fine series of architectural drawings, mostly made in the *École des Beaux-Arts*, belonging to the department. On a lower line is hung from day to day the current work of the School, all the drawings made by all the classes being exhibited here in a sort of "continuous performance." The comment to which it is thus exposed makes official judgments and criticisms almost unnecessary.

The department library, which, like this corridor, is sixty-five feet long, is one of the largest and best lighted work rooms on the grounds. Here are the six or eight hundred books and the fifteen thousand photographs which constitute the equipment given to the department by Mr. F. A. Schermerhorn in 1882, and since then constantly increased by the liberality of the trustees. Here also are innumerable folios, making up what is virtually an enormous scrap-book, with thousands of prints and engravings, classified under different heads. These are partly gathered from journals and magazines, but in addition a good many valuable books of plates have been taken to pieces and the prints mounted on cloth or cardboard and put into this collection. It is easily understood that this greatly increases their serviceableness, especially during the annual season of "historical research," when fifty or sixty men at once are ransacking the collections to find special illustrations of special topics of study. Books that would otherwise be accessible to only one are thus made useful to a dozen.

The staircases are lined with the unique collection of plaster models made at Blois for use in the interior decoration of Mr. Cornelius Vanderbilt's house in Fifty-seventh Street, given by him to the Schools of the Metropolitan Museum, and on the discontinuance of those classes presented by the Museum, with his cordial appro-

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bation, to the School of Architecture. They comprise several hundred pieces, mostly copied, on a reduced scale, from the famous staircase of Francis the First. With them came a number of valuable drawings made by the late Henry O. Avery, and the models from which were carved the beautiful modern Gothic capitals in the interior of the Academy of Design, in Twenty-third Street.

At the entrance of the first-year drawing room has also been set up a copy of the large model of one corner of the Parthenon made for the Department of Architecture of Harvard College, and also presented by Mr. Schermerhorn. It was made in Boston by Mr. C. G. McGregor, from drawings by Professor H. L. Warren, of Cambridge, and was executed under his personal supervision. This room, cleared of the packing cases which last term encumbered it, has been assigned to the first-year class and proves to be an admirably lighted draughting room. This leaves the northwest room free for drawing from the cast and for instruction in water-colors. It is a delightful room, better situated than any on the grounds, the windows commanding views of the New Jersey shore and of the Palisades and of the Hudson River from Hoboken to Tarrytown. Here also the fourth-year men and the post-graduate students meet once a week and read to each other the papers they write, and exhibit the drawings they make, in fulfillment of the requirements of the course in Advanced Architectural History.

Of these post-graduate students mention has already been made in the July number of this journal, which described the scheme adopted in 1891, under which draughtsmen of experience were admitted on the same footing as college graduates. This scheme has now been slightly modified, though retaining its principal features. It has in the main worked well. During these six years, besides eighteen college graduates, sixty-six professional draughtsmen have been in attendance for periods varying from two months to three years, most of them spending at least a year in the School, and nearly thirty staying two years. Six have finally joined the regular fourth-year class and taken their degree in due course. These special students have for the most part been men of proved ability and experience, and their presence has palpably raised the character of the school. Indeed, it is mainly in such students that we can expect to find the maturity of character and the professional skill which are needed to enable men

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really to profit by the exceptional advantages of our position. At present the museums and libraries, and the buildings, public and private, by which we are surrounded, and which themselves constitute an architectural museum of priceless value, are of comparatively little service. Most of our students are not old enough nor far enough advanced to make the most profitable use of them.

Moreover, while most of our regular students come from this city and its immediate neighborhood, as is the case in the College and in the other professional schools, sixty per cent. of these special students have come from other States, mostly in the West and South, as against thirty-three per cent. in the Medical School, twenty per cent. in the Law School, eleven per cent. in the Schools of Applied Science, and eight per cent. in the College. It is plain that our best chance of gathering students from the country at large is by encouraging the attendance of this class of men.

But in some respects things have not worked just as was expected. It was supposed that men of this maturity and experience would be able to take part without difficulty in the University Courses in History and Design, which are identical with the work of the fourth year, which is also of a post-graduate character. But though they have all taken part in the Historical studies, and have done so with profit, not a single man has presented himself, whatever his age and experience, who has been ready for our fourth-year work in Design. They have had to begin with the third or second-year work, and even that, in many cases, only after some weeks practice in the work of the first year.

As it has thus become plain that the offices do not, at present, furnish students ready for really post-graduate work, these students will hereafter be received not as university students, but on the footing of the special students who, as the Circular of Information says, may be received "for reasons of weight," and three or four years of professional experience will in general be held to be a sufficiently weighty reason in each case.

The provision that they may attend for briefer periods than one term, coming for two months at a time, has proved every way beneficial and will be continued. The position of professional draughtsmen at the beginning of their career is a precarious one, depending upon the condition of business, and the less well trained among them are liable constantly to find themselves with several months of enforced leisure on their hands. It is a great advantage

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to such men, and it is no inconvenience to us, for them to join our classes in design for two or four months at a time, taking up the current problems and doing such other work as they may be qualified to take part in, thus turning their ill fortune to serious profit.

The fee for each period of two months is now set at thirty dollars, which includes the privileges of the draughting room and four hours of lecture or recitation.

It is an interesting circumstance, as I have elsewhere pointed out, that the existence of these men in the school, side by side with the regular students, enables us to try the experiment of conducting, along with our present curriculum, a freer system of study. These special students, like the students in a European university, study whatever subjects they wish, in whatever order they are prepared to take them up, the only requirement being that they shall be of mature age and shall be qualified to pursue them to advantage and that they shall take the regular examinations at their conclusion. The two methods go on harmoniously together, and both are contributing in different ways toward the growth and development of our undertakings. But as the exceptional opportunities offered to professional draughtsmen become better known we may expect that they will constitute an increasingly large proportion of our students.

The Avery Architectural Library in its new and handsome room is prominent among the increased facilities of the School. A well-lighted draughting room, equipped with tables for various kinds of drawing, has been opened in direct connection with the book-room. Here a considerable number of men can be accommodated, with their drawing boards and apparatus, without crowding the book-room itself. This perfectly meets the needs of the second and third-year classes during the period given by them to historical research, and of the fourth-year men in their studies in Advanced Architectural History. The hospitalities of this room, as of the rest of the Library, are cordially offered to students and architects from the outside.

The methods of teaching, either in construction or in design, are not of course affected by change of place, except so far as increased facilities and further experience have given them a new development.

The chief extension of our work, this year as last, has been in the elective course in Advanced Architectural Engineering, given

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in the fourth year as an alternative to the elective course in History and Design. This course is an elastic one, the choice of studies being made to suit each student's needs. Last year the work was largely of a practical character, involving the study of modern engineering appliances and of buildings in process of construction. This year it has taken a more strictly mathematical and scientific shape, so that while last year the work was conducted entirely within the Department of Architecture, this year we have availed ourselves of the resources of our environment, enjoying the privileges of the Department of Civil Engineering. It has been gratifying to find that our previsions in laying out our own work of this kind have been measurably justified by the event, and that the minimum course of Mathematics, Mechanics and Engineering, which we administer under the title Architectural Engineering, has proved to be not altogether an inadequate or unsuitable preparation for these more advanced studies. We did not mean that it should be, but it is gratifying to find that it is not. The proof of th pudding comes in the eating, and this is the first time that this particular dish has been served up,

The most noticeable novelty within the range of the more strictly professional work has been setting the first-year men to measuring actual work and drawing it out, first full size and then to a reduced scale. Every member of the class that entered the school in October has lately made drawings of the porch of Havemeyer Hall from his own figures and then cast the shadows and rendered it in color, plan, elevation and section. A little later in the year the next class will take part in similar work on a more extensive scale. The new buildings offer an admirable opportunity for these exercises, which take the place of the work of drawing and measuring that for two or three years occupied a part of the autumn, but which it now seems better to abbreviate and to place at this time of year. The summer work will hereafter be made to consist largely of such drawings, for which these exercises will have furnished the necessary preparation.

The experiment has also been tried this winter of inviting architects in practice in the city to pass judgment upon the successive problems in Design of the fourth-year men. A different jury, consisting of two persons, has served each time. The drawings are sent to them and are returned with their written report and criticisms which are read to the class and are supplemented by the more detailed comments of the instructors.

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At the same time a variation has been made in the conduct of the work in Design which is calculated to compass two important ends, supplying two conspicuous omissions.

When a problem is completed and the drawings hung up for judgment they seem to be immediately transfigured. Unsuspected defects reveal themselves; neglected opportunities cry out to be improved. This comes naturally and inevitably from the new relations in which they are placed and from their comparison with one another. They are seen in a new light. When to this is added the detailed criticisms of a jury, every man feels as if he were now just beginning to understand the problem, and is eager while the impression is still fresh to take a hold anew and do things as he now sees they ought to be done.

This, of course, cannot be. Life is not long enough to do everything twice over; the academic year certainly is not. The impulse also, however genuine and sincere, would hardly last to carry men contentedly through what would be largely a mere repetition of work that had lost the element of novelty. But what we have done is this. We have had all the men put their designs into perspective, and then study them anew, with a view of remedying not only the defects pointed out by the jury, but those which the perspective drawing itself has revealed. This double interest serves to carry the student through the work of revision, a work in which, though he is going over familiar ground, he is by no means treading in his own footsteps. Every line he draws is a new one. Moreover, the work is not too laborious, since a sketch suffices to determine the proportions and the sky-line, and it then only remains to bring the discussion to its legitimate result by making a new drawing, a tracing will suffice, to show what changes must now be made in the elevation, to make it correspond with these new developments.

Nothing can be more salutary than this experience. It enables the student to profit at once by the special criticisms his work has received, and to put to immediate use the ideas they have suggested while these ideas are still in that "nascent state" which, in Design as in Chemistry, is the condition most favorable to new combinations.

These exercises also afford a legitimate opportunity for making drawings in perspective, without introducing them as a separate exercise in draugtsmanship, out of relation with the main current

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of school work. Even a sketch is of value as making the theory and practice of this branch of Applied Geometry easy and familiar, but if the drawings are carefully finished, the skill attained is an important addition to the resources of the architect and one which the professional draughtsman can hardly afford to go without. The rendering of perspective drawings, whether with pen or pencil, or with the brush and in color, is an art by itself, which it is well to practice on occasion. These exercises in revision afford just the needed opportunity.

Not the least of the advantages of the new site is the pure and bracing atmosphere that we breathe. We are only one or two hundred feet above the river, but the place has the flavor of a mountain top. We all agree that we have never been so well and happy as since we have lived among these exhilarating breezes with the "wide aerial landscape" everywhere before our eyes.

THE CHRONOLOGY OF THE MISSISSIPPI SYSTEM.

By JAMES L. GREENLEAF.

A glance over the map of the United States shows the vast extent of country which the Mississippi drains. The comprehensive reach of its great tributaries to the east and west, justifies the assertion that they cover every variety of topography, and are affected by all possible extremes of climate. Rich farms stretch mile upon mile over the gently undulating land from the Alleghanies westward. The distant water sources are laid in the wild scenery of the Rocky Mountains. One may steam in the drenching rains of southern swamps, or escape to the dry invigorating air of arid plains. If you seek a semi-tropical vegetation, it is found in the low lands of Louisiana, while an Arctic winter holds high carnival on the prairies of Dakota when the blizzards howl. One and all of these regions, comprising every variety of heat and cold, wet and dry, high and low, cultivated and wild, unite in pouring their surplus waters into the great resultant known as the Mississippi.

Varied are the topography and climate of the Mississippi watershed and, in consequence, equally varied are its rivers. It is true that the chief agents controlling the periods of high and low water

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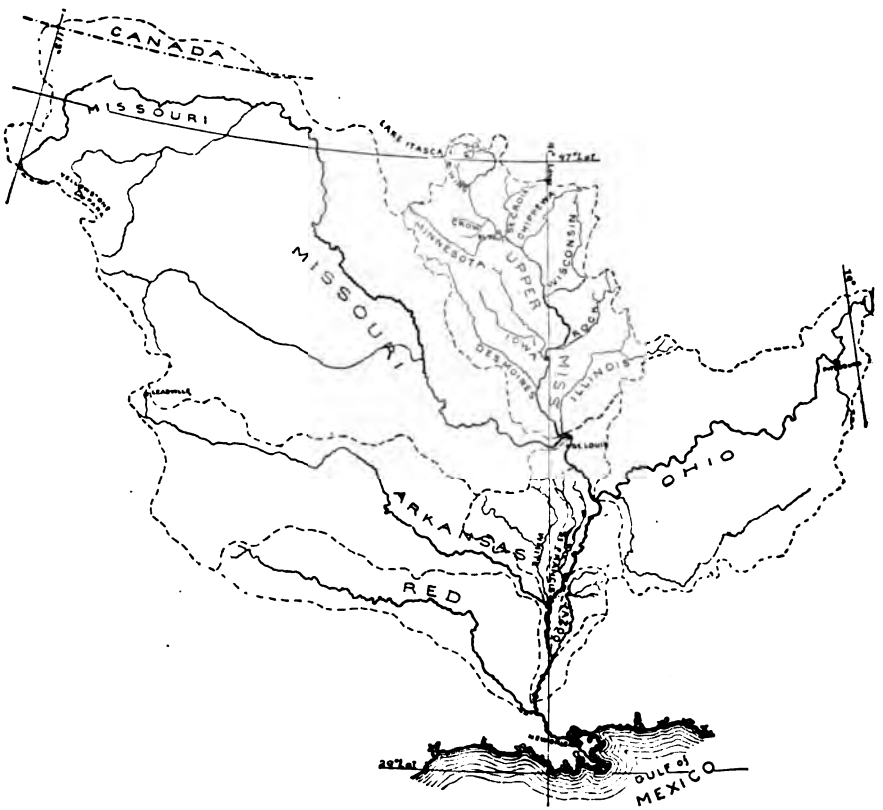
in a stream are the fluctuations in rainfall and in temperature through the successive seasons of the year. Yet there is not a distinctive feature in the topography, soil or vegetation of any division of a watershed which does not impress itself on the local water course, exerting an active, although subordinate influence

MAP OF THE MISSISSIPPI WATERSHED.



SUBDIVISION.

Upper Mississippi,	173,000	Sq. Miles.
Missouri,	528,000	" "
Ohio,	214,000	" "
Arkansas,	161,000	" "
Red,	97,000	" "
White, St. Francis, Yazoo, and remaining area,	86,000	" "
Total of Mississippi Watershed,	1,259,000	" "

upon the fluctuations of flow. These factors act sometimes in co-operation with the variations in intensity of rainfall and tempera-

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ture, often in opposition to them and one another, and the result is an intricate play of ever changing conditions. Silent forces in the water, air and sunshine are continually at work shifting and interlacing with bewildering complexity; yet holding one another in a delicate poise which floats, undulating with subtle meaning, upon the rising and falling surface of the stream.

If this play of forces controlling the flow is complex, however limited the watershed, what must it be in the case of a great drainage system with its many important branches! The influences stamped upon each side stream are in that case carried down to blend in kaleidoscopic changes upon the sensitive surface of the main river, the sleepless, infallible recorder of them all.

The term the great resultant is, therefore, well justified in speaking of the Mississippi. Were the eyesight keener one might see all the countless impulses gathered from a million miles of country reflected in that single channel; he could read to the full the meaning which its rising or falling waters carry in their flow.

This intricate adjustment of forces is in operation everywhere over the one and a-quarter million square miles of the Mississippi watershed. Each of the great divisions belonging respectively to the Missouri, Upper Mississippi, Ohio and other rivers, as shown on the map, has its peculiar features of climate and topography, which are thus stamped upon the rise and fall of the river itself. A study of the Mississippi system from this standpoint, condensed to the most concise terms possible, affords the following record of the average chronology of flow. All the rivers tributary to the Mississippi show a decided tendency toward low water in the autumn. This condition is liable to be varied by a sudden and brief fall freshet. The southern rivers begin to fall from a high stage in June and the northern rivers in July. All begin to rise from low water in the latter part of winter. The southern rivers show an increasing flow in January, the Ohio in late January, the Missouri and Upper Mississippi in February. Two principal freshets occur during the year in each of the large tributary basins. Considered broadly, and for all the large rivers, the period from February into June covers the times of occurrence of these highest two stages. Between them a fair, or even high state of flow is maintained. There is a tendency for the higher of the two rises to occur in late winter or early spring on the southern tributaries, whereas the Upper Mississippi and Missouri reach their

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culminations in the latter part of spring and summer. The coincidence of high flow upon more than two of the large branches is extremely rare, and hence it is an exception for the main river to be subjected to the enormously congested state which would otherwise result.

The foregoing statement of times of high and low water deals solely with effects; it mentions nothing of the causes producing these effects, neither does it relate the one to the other. In view of the intricate play of conditions which have been shown to influence the chronology of flow of streams, such attempt to relate cause and effect might well seem hopeless. He would soon be lost in a bewildering maze who endeavored to unravel all the threads of detail which enter the subject. As the variation in intensity of rainfall and temperature are, however, the principal factors and, for the Mississippi system, have such dominant influence that other causes sink from view behind them, it is entirely possible to see the influence of these two causes and trace their relations to the varying depths of water in the streams. The impossible thus becomes attainable, and the hopeless task resolves into an interesting study.*

It is true that to discuss the subject within the limits of a single paper the story must be briefly told, so briefly as to possibly seem to the student of the Mississippi a mere touching here and there upon the subject he is pondering, careless and superficial as the dip of the swallow skimming the surface of the water. But no apology is called for, even to the student. When looking upon a landscape there is a certain advantage in a distant point of view, in that it affords a wider comprehension of the country as a whole than if one were in the midst, spying out each ravine and searching with the geologist's hammer into the structure of the rocks. So it may well be that by resolutely viewing the Mississippi system in broad prospective, one can realize something of the comprehensive laws which govern the flow of the rivers, and see the causes of their rise and fall with the alternating seasons of the year. Details are lost to sight on this larger horizon, but in their stead the changing seasons are mirrored in the streams, and the march of law is seen as the sweep of cause and effect moves in grand procession over the watershed of the Mississippi.

* See papers upon this subject by the writer in the *American Journal of Science* of July, 1896, and the *Engineering Magazine* of March, 1897.

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Considered thus broadly, there exists a wave of special concentration of the yearly rainfall. A point in time is, as it were, a nucleus toward which the intensity of rainfall has been increasing during the past weeks, and from which it diminishes into the future. This nucleus passes with wave-like progress through time and over the surface of the country. Starting from the Gulf in late winter it travels slowly northward up the less elevated lands of the Mississippi, climbing at the same time the plains leading to the western mountains. The northern portions of the watershed are reached in June and July. There is a similar wave-like progression of the period of melting of the snow and ice. From its imperceptible beginnings in the southern low lands it travels northward like the rainfall wave, also spreading east and west upon the elevated country. Its last traces are seen late in summer in the far distant mountain sources of the Missouri, and doubtless there are caves and deep ravines high in the mountains where it retires to rest until the triumphal progress of another year. Keep the progression of these two waves of rainfall concentration and melting mentally in view and note the corresponding rise and fall of the rivers. It is then possible to catch the rhythm of nature's harmonies and realize that design is silently passing its firm hand across the country.

In the heavy rains of late winter at the south is seen the coming of the rainfall wave. All the southern streams are forced to renewed activity by its vigor. At the same time the wave of melting rises from the southern country, gently as the first blush of dawn. There are halts and starts as the weather fluctuates, but on the whole the advance is steady. It precedes the wave of rainfall concentration and travels more rapidly. As it reaches further into the regions of snow and ice its crest is more pronounced, its action more decided, until on the banks of the Missouri, the ice gorges are piled many feet in height. The wave of melting does not act alone, but with the rains, which, by their increase, are giving evidence that the wave of rainfall concentration is to follow. While the wave of melting is passing up the watershed of the Ohio, and is largely causing in February or March the greatest freshet of the year, it is at the same time covering the lower tributaries of the Upper Mississippi and Missouri. With the aid of the increasing rains it brings the former river in March to the crest of the secondary rise, but the Missouri does not reach its similar culmination until April.

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The wave of rainfall, in its full intensity, swept the lower portion of the Arkansas watershed in February, and forced the river to a freshet which was probably the greatest of the year. It slowly expands over the Arkansas watershed and eastward upon the Ohio. In April or May it gives the secondary freshet to the Ohio and, diminished in vigor, combines with the wave of melting upon the elevated sources of the Arkansas to cause a freshet which is usually the greatest for that river. April or May sees also the wave of melting reach the lake region at the sources of the Upper Mississippi and, with the rainfall, create the secondary freshet there.

Gradually, as spring passes into summer, the wave of rainfall concentration invades the country of the Upper Mississippi and Missouri. Upon the former river it causes the highest water of the year, possibly as early as April, but generally sometime from late May to July. During June, when it is still aided somewhat by the wave of melting which is passing into the western mountains, it carries the flow of the Missouri to its highest point. In June to July the rainfall wave reaches the sources of the Upper Mississippi, bringing a freshet which is often the largest for that region, and so it disappears off the Mississippi watershed.

Behind the wave of rainfall concentration as it passes over the country, is seen a wide and continued prevalence of light rains, resulting in a wellnigh universal falling of the depth of water in the rivers. The southern rivers begin to yield in June. The northern streams hold on into July, but they finally shrink from the encroaching drouth. September sees them all completely fallen from their high estate. This universal calm, when the energies of the waters are at low ebb, and the sun broods hot over the land, is often rudely broken by fall rains which may swell the rivers to sudden floods that as rapidly subside. But even as the thunder storm rising in the evening of a sultry summer day serves to intensify the calm it breaks, so the fall freshets, if they occur, emphasize the diminished activity and universal low water upon the Mississippi watershed in the closing season of the year. Then the cold of winter floats down like the Angel of Death, drawing its white pall over the sources of the northern streams, and they dwindle in their channels. The rivers of the south run low. The cycle of the year is complete, and the Mississippi watershed is lying in quietness, waiting for the January rains to herald the activities of another year.

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A SLIDING STADIA ROD.

By GILBERT THOMPSON.

While engaged in topographical surveying during 1897 I designed and used a sliding stadia rod which I found very convenient, and submit a drawing and description of it which may be of interest and service to the readers of the QUARTERLY.

It is constructed of straight well-seasoned pine wood, three-fourths of an inch thick when planed, and consists of two parts, the case and the slide. At the top of the latter is fastened the target, which is graduated to tenths and hundredths of a foot, it being assumed that the stadia wires are so set that one foot interval on the rod corresponds to a distance of one hundred feet on the ground. The slide is raised when required, two or four feet, and held firmly and exactly in place by a pin.

The graduation is printed in dull black and white to avoid reflections. A light red is used instead of white on the slide, to indicate that it is raised, and how many feet. No numbering is used, the even feet are counted as also the decimals of a foot from the target, it being the practice to set the lower stadia wire on such a foot mark as will bring the upper stadia wire across the target. For some constant dark backgrounds scarlet vermilion may be found occasionally preferable to black. Shiny preparations of pigments should be avoided, as well as varnish. A small square (0.2 foot) is painted, either black on the four-foot space, or white in the five-foot space, at the average height of the telescope, for use in the vertical angles. A square of paper may be used until this height is determined. The remaining portions are painted a neutral tint.

The slide is held in the case by three brass bands, the center one is placed at a convenient height for the rodman, through which a small but stiff metal pin passes; this goes also through the slide and clear through to the opposite side of the case. This pin should be straight and fit closely. The slide should be in proper position and snug down in the case when the hole is bored through it to receive this pin, and should be of the same diameter. At exactly two feet and four feet below this pin-hole are bored holds in the slide for the same purpose. A sliding slot is cut at each hole, to aid in setting the pin quickly. A finger hole is at the foot of the slide.

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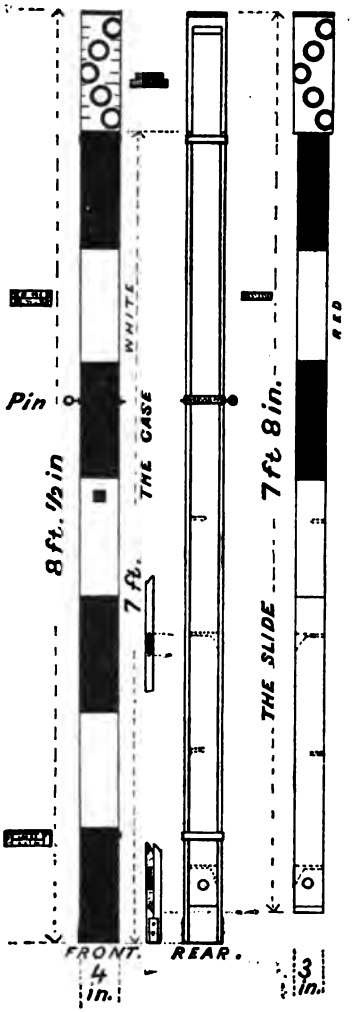
At first, I considered this arrangement of holding the slide in place as a make-shift, but it proved to be so easily worked and held

SLIDING STADIA ROD.

Gilbert Thompson, 1897.

ROD CLOSED.



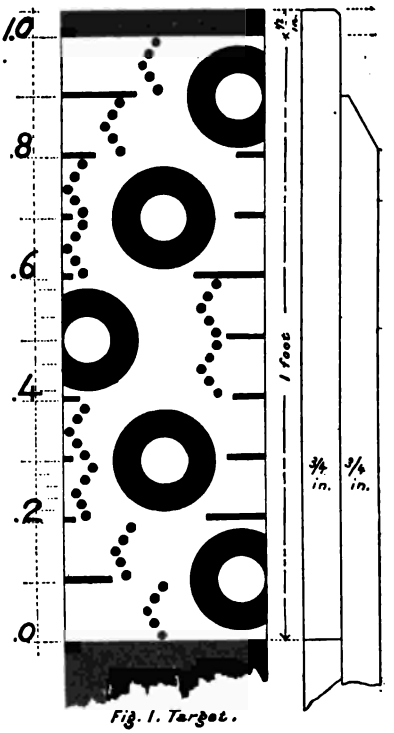


Fig. 1. Target.

the slide so firmly in position, that I cannot after several months' constant use recommend any other contrivance.

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For short distances it would probably be found preferable to also graduate the back of the slide, sub-dividing the second and fourth foot space from the bottom, the same as the target. This would admit of the rod being also used as a level-rod, which is occasionally desirable. This would require holes to be bored one foot apart on the slide and opposite the others. These should be only deep enough to admit about half the pin, the rod being raised one foot or more as required to bring the target to the center cross-hair. If the bands only touched the edges of the slide, a flexible self-reading rod could be fastened there instead of making a graduation.

A seven-foot case furnishes an extension to twelve feet, and a nine-foot case on the same principle, would extend to sixteen feet.

Such a rod can be made by any country carpenter. The circles on the target are very nicely struck with an adjustable bit, the cutting giving additional sharpness and distinctness to the graduation. With the aid of the diagram and this brief description, I believe its construction in the field will be found practicable.

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ABSTRACTS.

METALLURGY FOR 1897.

By Joseph Struthers, Ph.D.

The following list of note references is composed of the more important articles on general metallurgical practice which have appeared in the scientific periodicals during the year 1897 :

Abbreviations Employed.

Amer. = American.	Mach. = Machinist.
Aust. = Australian.	Mag. = Magazine.
Can. = Canadian.	Manuf. = Manufacturer.
Chem. = Chemical.	Mech. = Mechanical.
Col. = Colliery.	Min. = Mining.
Eng. = Engineering.	Rev. = Review.
Guard. = Guardian.	Sci. = Scientific.
Inst. = Institute.	Soc. = Society.
Journ. = Journal.	Trans. = Transactions.

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DEPARTMENT OF METALLURGY, SCHOOL OF MINES, COLUMBIA UNIVERSITY,
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ANALYTICAL CHEMISTRY.

BY ELWYN WALLER, PH.D.

Flocculation in Laboratory Work.—Greig Smith (J. S. C. I., XVI., 872). The action of certain salts, bases, etc., in causing precipitates to coagulate into masses, has been shown to be practically identical with the coagulation of colloid bodies by electrolytes (Proc. Lond. Chem. Soc., 1891, 176; see also Trans. Lond. Chem. Soc., 1892, 160, and 1895, 63). Trivalent elements were found to have the greatest coagulating power, bivalent elements about one-tenth as much, and monovalent elements about one-five hundredth. The order of efficiency of the alkalies is NH_4, K, and Na.

$BaSO_4$ is flocculated by HCl, but NH_4Cl or NH_4NO_3 is quite as efficient. A volatile base is necessary, as some adheres to the precipitate. The use of NH_4NO_3 in precipitation of P_2O_5 by molybdate is also an example of the use of a flocculant.

For AgCl, HNO_3 is usually recommended, but in cases where volumetric estimation by precipitation is employed the addition of a little $Al_2(NO_3)_6$ is more satisfactory (Gay Lussac bullion assay, etc.).

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In the titration of Mn by $K_2Mn_2O_8$ Ferric salts are equally efficient with Zn salts in producing flocculation. The case appears anomalous, since Al or Ba salts do not seem to have the desired effect.

In separating Co_3 Fe_2Cy_{12} or $Ni_3Fe_2Cy_{12}$, NH_4Cl is a good flocculant. The action of alkalies, their carbonates, phosphates and oxalates is anti-flocculant in most cases. Lime and metallic hydrates have some flocculating effect, in some cases very marked.

In the Fehling test for sugar, KOH is superior to NaOH in affording a dense precipitate, and the addition of K_2SO_4 (2 gms. per test) is especially effective.

Alkalimetry, etc., Applied to Metals.—Lescoeur (Bull. Soc. Chim., XVII., 26 et seq.). If to solution of neutral salt of a metal (as Al), phenolphthalein is added, and then standard alkali is added, the red alkaline tint of the phenolphthalein will not appear until all of the oxide has been precipitated; litmus acts in the same manner, but much less sharply.

If methyl orange is used as indicator, the alkaline color appears at once if the salt were neutral—if the solution contain free acid, the acid color disappears when the free acid has been neutralized, and precipitation is just beginning. In other words, phenolphthalein indicates the passage from neutrality to alkalinity, methyl orange indicates the passage from acidity to neutrality. By utilizing these facts many bases may be quantitatively determined by use of acidimetric solutions. With the salts of some metals affording colored precipitates, as ferric salts, etc., by dilution, and a little practice for the eye in recognition of the tints, the titration may be effected with good results.

Sodium Bicarbonate.—Lunge (Zts. Angew Chem., 1897, 169). This depends upon the fact that $NaHCO_3$ is converted to Na_2CO_3 by NaOH. A spot test with $AgNO_3$ is used, which gives a brown coloration when a slight excess of the standard NaOH solution has been added. To prepare the standard NaOH solution, a solution of Sp. Gr. 1.16 is made, a little $BaCl_2$ added—and then $Ba(OH)_2$, after which it is diluted to normal strength.

Estimating Potassium.—Mercier (Bull. de l'ass'n Belge, 403). By precipitation and weighing of the metallic Pt. in K_2PtCl_4. After obtaining the precipitate in the usual manner, it is dissolved in boiling water, and Hg_2Cl_2 added little by little to the boiling solution, until an excess is deposited on the bottom of the beaker. After five minutes' boiling 1 or 2 cc. HCl are added and it is boiled again. On cooling and filtering, all the Pt is found in the precipitate, which is washed, ignited and weighed, affording pure Pt. The weight multiplied by 0.4835 gives K_2O present.

Alumina and Farric Oxide in Phosphates.—Lichtschlag (Chem. Ztg. XXI., 264). Two gms. of the sample are fused with 8 gms. Na_2CO_3, then dissolved in water, the portions adherent to the crucible being dissolved off with HCl. Altogether 100 to 125 cc. of HCl. (Sp. Gr. 1.095) are added. After digestion for ten minutes at 50° to 60° C. the liquid is transferred to a 200 cc. flask, neutralized with NaOH, heated to boiling and 30 cc. of a 20 per cent. NaOH solution added. After digestion for fifteen minutes with frequent shaking the solution is made up to the mark, the contents well mixed, and 50 cc. taken for determining Al_2O_3. Fe is determined in the precipitate by dissolving, reducing and titrating with

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$K_2Mn_2O_8$. To the 50 cc., HCl is added, and the solution evaporated to dryness, taken up with HCl, and precipitated boiling with ammonia, and the precipitate of $AlPO_4$ washed with hot water. The addition of a little alkaline phosphate before precipitation is of advantage.

Iron in Ores.—Reinhardt (Chem. Ztg., XIII., 323). The method recommended is a combination of the reduction as for dichromate titration, and Zimmerman's ($MnSO_4$) permanganate titration. The ferric chloride solution (hot) is reduced by $SnCl_2$, the excess of reducing agent removed by addition of $HgCl_2$, some $MnSO_4$ added, and the solution titrated with standard $K_2Mn_2O_8$. This latter is used with free H_2SO_4 and H_3PO_4. The latter acid is especially useful in preventing a brownish coloration when the titration is only partly completed, and effects a sharp end reaction. The $MnSO_4$ solution is prepared by mixing 1 litre of water containing 200 grms. $MnSO_4$ and acidified with H_2SO_4, 1 litre of H_3PO_4 of SpGr 1.3, 600 cc. of water and 400 cc. conc. H_2SO_4. 60 cc. of this solution is used with each titration (on 0.5 to 1 grm. of ore). Mixer and Dubois propose a modification in that the ore is dissolved by HCl with with the addition of some $SnCl_2$ (insufficient to quite reduce all the Fe present) adding more $SnCl_2$ after solution has been effected, and then proceeding.

Zinc Titration.—Ballard (J. S. C. I., XVI., 399). In titrating with standard Na_2S, the end-reaction may be sharply determined by "spotting" on a bright silver foil. ZnS does not affect the silver unless the solution is strongly ammoniacal, but one part of Na_2S in 20,000 of water gives a brown stain in 10 to 20 seconds.

Nickel in Nickel Steels.—Spüller (Chem. Ztg., XXI., 243). 2 grms. of the sample are dissolved in 60 cc. of HNO_3 (SpGr 1.2) and the nitrous fumes boiled out. After cooling the Fe is precipitated out by ZnO, and the solution diluted to 250 cc. After thorough mixing and settling, the tint of the solution is compared with that of solutions obtained from corresponding amounts of standard samples containing known amounts of Ni, which have been treated in the same manner.

Separating Tin, Arsenic and Antimony. Dancer (J. S. C. I., XVI., 403). Treating the mixed sulphides with $Ca(OH)_2$ and heating to 80°C. dissolves As and Sb sulphides—leaving Sn completely separated from Sb, in an insoluble crystalline compound the nature of which has not been determined, but soluble in cold dilute HCl, or in dilute HNO_3 or H_2SO_4 it is also soluble in $(NH_4)_2S$. If the As is present in amount not exceeding 5 to 6 per cent. of the Sn, it all goes with the Sb into solution. In larger amounts it is likely to form Ca_3AsO_4 or Ca_3AsO_3 by standing and to precipitate in these forms. The As in solution with the Sb may be separated by adding strong ammonia (5 cc. for every 100 cc. of solution), heating to nearly boiling, adding glacial $HC_2H_3O_2$ drop by drop until a slight permanent precipitate is formed and then boiling when Sb_2S_3 separates in dense flocks from the solution which should still smell of ammonia. Acidifying the filtrate with HCl will cause separation of As_2S_3.

Qualitative for Arsenic and Antimony.—Conradson (J. S. C. I., XVI., 518). The method described is a systematic application of Hager's test (paper wetted with $AgNO_3$ held in the gases evolved by the action of acid upon metallic Zn or Mg in presence of the substance tested) with use of another test paper ("nitro iodine") to differentiate As

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and Sb. Four test papers are used, freshly prepared and still moist, viz: 1 Drop of Pb $(C_2H_3O_2)_2$, 2 of $AgNO_3$, 3 of $HgCl_2$, 4 "Nitro iodine," two drops HNO_3 (SpGr, 1.20) and two drops of a 10 per cent. solution of KI. Paper 1 is used to test for freedom from H_2S in the gases which may be at first perceptible in many cases and then disappear. If it still persists in a blank preliminary test, a fresh portion of Zn and H_2SO_4 must be tried before introducing the solution from the substance. The solution from the substance may be prepared as recommended by Hager. The strength of the acid used should be such as to give a moderately slow evolution of gas to which the test papers are exposed for 10 to 15 minutes each. After blank tests with the reagents introduce the solution of the substance, allow the gas to act for 15 minutes each upon the papers introduced in the order indicated. The colors will be:

1. Pb paper. S brown to black.
2. Ag paper. As or Sb, brown to black.
3. Hg paper. As alone, yellow to yellowish brown.
3. Hg paper. As and Sb, yellow to brown.
4. Nitro iodine. Sb, bright yellow to orange.
4. Nitro iodine. As or H, no color.

Titration of Stannous Salts.—Young (J. Am. Chem. Soc., XIX., 809). Stanuous salts can be titrated accurately in acid solutions by standard I solution, provided no other oxidizing or reducing substances are present. The solution of the stannous salt must be protected from exposure to the air, as it oxidizes very readily, and no iodate should be present in the I solution.

Volumetric for Antimony.—Hanus (per Chem. Ztg., 1897, 324). After filtering and washing a precipitate of Sb_2S_3 the precipitate (paper and all) is boiled with an excess of $Fe_2(SO_4)_3$. The reaction occurring is:

$$Sb_2S_3 + 5Fe_2(SO_4)_3 + 8H_2O = 2H_3SbO_4 + 10FeSO_4 + 5H_2SO_4 + S_3.$$

The resulting $FeSO_4$ is titrated with standard $K_2Mn_2O_8$. Results are correct only within ±0.3 per cent.

Dissolving Platinum.—Méker (C. Rend, CXXV., No. 24). If one fuses carefully six parts of $(NH_4)_2SO_4$ (at about 300°C.) and then adds one part NH_4Br with sturring, the mixture attacks Pt with energy (at about 330°C.), frothing up and evolving fumes of sulphate and bromide. When dissolved in water and filtered, vermillion red $4NH_4Br.Pt\ Br_4$ remains practically insoluble in solutions of ammonium salts, but soluble in boiling water. In cold water it dissolves only to the extent of about one part in 200.

Copper Estimation.—Söderbaum (Berichte, XXX., 902). Precipitation by acetylene in ammoniacal solution gives a complete separation. The salt is dissolved in 100 to 200 times its weight of water in a flask, made ammoniacal and the C_2H_2 passed through it. Warming hastens the reaction and affords a precipitate more easily managed. After filtering and washing, the precipitate is digested with warm dilute HNO_3 for 30 minminutes. The black residue is filtered off and ignited separately to CuO. The solution is also evaporated and ignited to CuO. Salts of fixed alkalies

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do not affect the precipitation, but it is retarded by ammoniacal salts. Precipitation is prevented by the presence of Zn, unless some SO_2 has been previously added.

Copper in Bearing Metal Alloys.— Garrigues (J. Am. Chem. Soc., XIX 934). The alloy is dissolved in HNO_3. Add a slight excess of H_2SO_4 and evaporate to expel volatile acids. Dilute and add SO_2 until it is in excess, showing the odor when gently warmed, precipitate with alkaline thio-cyanate—filter and wash thoroughly. Transfer filter and contents back into the beaker in which precipitation was effected, boil with a measured excess of a standard NaOH for a few minutes, cool and dilute to a convenient bulk—(say 200 cc.). After passing through a dry filter take an aliquot portion (say half = 100 cc.) and titrate to neutrality with standard acid, using methyl orange indicator. The alkalinity which has been destroyed is the measure of the Cu present, the reaction being: $2CuCNS + 2NaOH = Cu_2(OH)_2 + 2NaCNS$.

Refined Copper.—Electrolytic Assay, Heath (Trans. Am. Inst. M. E., Lake Superior meeting, July, 1897). The percentages of impurities affecting the quality of the copper are to small to be capable of estimation on amounts less than 5 gms.

For electrodes it is best to use Pt. spirals and cylinders, the latter split down on one side.

For sources of electricity the crow foot gravity cells *may* be used. They should be overhauled twice a month. When half the zincs have been dissolved off they should be replaced. Recast with addition of an equal amount of spelter. In starting, fill up with old battery liquid to get immediate activity. The best source of electricity is a dynamo current with incandescent lamps, combined with storage cells. The "chloride accumulator" has been found very good. A voltmeter and rheostat are necessary adjuncts.

The analyses should be connected in parallel. For the solution H_2SO_4 is preferable, containing HNO_3 in amount not quite sufficient to form NH_4HSO_4 by the action of the battery. As or Sb should be removed by evaporation with Cl or Br. To test for the completion of the separation freshly prepared H_2S water is best. It will indicate 0.000001 gm. Cu in 1 cc. K_4FeCy_6 is readily rendered uncertain in its indications by the presence of small amounis of Fe.

Method.—Dissolve 5 gms. in a small breaker in 20 cc. of HNO_3, add 5 cc. conc., H_2SO_4 and evaporate until dry (or white fumes). Cool, add 2.7 cc. HNO_3, dilute with 30 cc. of water, warm until dissolved, dilute to 120 cc., insert the electrodes and connect up. Use a current of 0.25 to 0.3 ampere. When the solution has been apparently colorless for 12 hours, test 1 cc. of the same with 1 cc. of H_2S water in a small white capsule. If any brownish color is apparent continue the action. When precipitation is shown to be complete, transfer the electrode quickly to a beaker of cold water, wash with water, then with absolute alcohol, ignite off the alcohol, cool and weigh. In the test experiments the time consumed in electrolyzing was 36 to 60 hours.

In the discussion of the paper Mr. Sperry stated that the most satisfactory method of determining As, Sb and Bi was Rivot's (separation of Cu by sulphocyanide). The presence of much HNO_3 to prevent the coprecipitation of Zn, etc., was found not to be necessary. Mr. Heath said that the most satisfactory method of separating Sb (preliminary to

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making the electrolytic assay for Cu) was that of Low, somewhat modified. The HCl solution of the Cu was evaporated with 2 gms. of S dissolved in 10 cc. of Br until the mass was pasty. The residue was then treated with 20 cc. of liquid Br, and evaporated on the sand bath until whitish fumes of $SbBr_3$ were no longer evolved. Only a trace of Sb remained with the Cu.

Silver—Scorification Instead of Cupellation.—Warren (Chem. News, LXXVII., 39). The lead button is placed on a bed of $BaSO_4$ or $SrSO_4$ pressed with a smooth pestle into a clay dish. A lump of the same bulk as the button, consisting of an alloy of Pb with 10 per cent. Bi is added, and the flame from a blast lamp (with foot bellows) is made to impinge upon the mass until it is brought to red heat. The flame is then shortened to give a strongly oxidizing flame, and the temperature of the regulus is raised to bright red. The PbO forms rapidly and is partially absorbed by the material of the cupel. The blast is kept up until only silver remains. If the amount of lead is large, it may be necessary to remove some of the PbO with a spatula as the oxidation progresses.

Vanadium Estimations—Browning and Goodman (Zts. Anorg. Chem., XIII., 427). Boiling a solution of ammonium vanadate with an excess of $H_2C_4H_4O_6$, of $H_2C_2O_4$ or of $H_3C_6H_5O_7$ causes a reduction to V_2O_4 which may be titrated by standard solution of I after adding excess of $NaHCO_3$.

Approximately ten times as much of the organic acid as there is V present should be used. Excess of $H_3C_6H_5O_7$ tends to give high results, which is not the case with the other two. MoO_3 is reduced by the same treatment, but WO_3 is not. It is preferable to add an excess of the standard I, and then to titrate back with standard As_2O_3 solution.

Selenium and Tellurium in Commercial Copper.—Keller (J. Am. Soc., XIX., 771). Precipitation in Ammoniacal solution by $Fe_3(OH)_6$ (Lehmann and Mager Am. Chem. J., VII., 172) is a satisfactory method of separating these elements from a solution of the commercial Cu. Dissolve 500 gms. or more of the sample together with a little Fe, in HNO_3, add enough NH_4OH to hold all Cu in solution, and the Se and Te will be found in the precipitate. Boil, filter and wash. The excess of iron required to separate Se is much greater than for Te.

The best precipitant for both is SO_2. To apply it (or H_2S) successfully both must be present in the *ous* form, which can be obtained by boiling with strong HCl. No heavy metals should be present, as they will also come down to some extent. Conduct the operation in the cold. Saturate the strongly acid solution In the cold with SO_2, let stand 20 hours, and then filter. In solutions containing from 30 to 50 per cent. of HCl of SpGr 1.175, both were completely separated. When the acidity was greater, some Te remained dissolved, and when at 80 or 90 per cent no Te was precipitated.

To separate them from one another the KCy method is very imperfect. Se is dissolved by it, but also some Te. In strong HCl solution Se is precipitated by $FeSO_4$. Te is not.

In solutions containing Se and Cu, Bi, etc., precipitation by H_2S and extracting the sulphides with Na_2S fails to extract all Se.

In presence of Cu the reaction with H_2S seems to be

$$SeO_2 + 2H_2S = SeS_2 + 2H_2O$$

$$3CuCl_2 + SeS_2 + 3H_2S = 2CuS + CuSe + 6HCl + 3S.$$

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SeS_3 forms in the cold (lemon yellow), but is partially decomposed by heating.

Quantitative Separation of the Halogens.—Carnot (C. Rend., CXXVI., No 3). The solution to be tested, brought to a bulk of 200 cc. and neutral, is placed in a globe stopcock bulb of about 300 cc. capacity. Then the addition of 10 drops of H_2SO_4 saturated with nitrous fumes (from the action of HNO_3 on starch) will set free only I. After shaking, 10 cc. of CS_2 are added, which take up the I. A little more of the nitrous H_2SO_4 and of the CS_2 is added, after running off the first lot of CS_2 through the stopcock, to insure complete removal of the I. Three treatments are sufficient. The CS_2 is run into a flask and washed with cold water, the first washings being returned to the original solution. The I can be determined by adding K_2HCO_3 and titrating with standard $Na_2S_2O_3$. After removing I, add a few cc. of 10 per cent. H_2CrO_4 solution and 3 or 4 cc. of H_2SO_4 (1:1). Stopper firmly and then float the stopcock bulb for 30 to 60 minutes on a water bath at 100° C. After cooling completely, only Br has been set free, which is extracted by use of CS_2, as in the case of I. To the CS_2 in a flask is added some KI and $KHCO_3$ and the titration effected as before by standard $Na_2S_2O_3$. In the remaining solution the Cl may be determined by precipitation with $AgNO_3$, or it may be calculated by difference.

Detecting Traces of Bromine.—Baubigny (C. Rend., CXXV., 654). This depends on conversion of fluorescein into the tetra bromo derivative—eosin. Paper is soaked in acetic solution of fluorescein and allowed to dry. When moistened and in contact with vapor of Br the paper will show a rose color. The solution to be tested is warmed with addition of $CuSO_4$ (6 gms.) and $K_2Mn_2O_8$ (0.7 gm.) and passing through it a slow current of air, which, after passing through the solution, is brought in contact with a bit of the moistened test paper. Free Cl in the solution interferes somewhat. In that case it is necessary to convert into chloride (and bromide) before making the test.

Carbon Monoxide.—Mermet (Bull. Soc. Chim., XVII., 467). A weak solution of $K_2Mn_2O_8$ acidulated with HNO_3 is decolorized by CO, the more rapidly the greaier the proportion of this gas. The reagent is prepared thus:

Solution A—2 to 3 gms. $AgNO_3$ in 1 litre of distilled water.

Solution B—Boil 1 litre of distilled water with a few drops of pure HNO_3, add solution of $K_2Mn_2O_8$ drop by drop until the pink tint holds. This is to purify the water from dust, etc. Cool, and then dissolve in it 1 gm. $K_2Mn_2O_8$ crystals and add 50 cc. of Pure HNO_3. Preserve this, protected from light and from dust.

Make up the reagent, when it is to be used, by mixing in these proportions: 20 cc. of A, 1 cc. of B and 1 cc. of HNO_3. The HNO_3 in all cases should be free from HCl and from lower oxides of N.

To make a test, take two bottles with ground stoppers and filled with water. Provide for each bottle a cork carrying a syphon, wherewith to draw off the water and an inlet tube plugged with cotton to prevent the entrance of dust. Empty one bottle in the place where the air is to be tested, and the other in the open air near by as a check test. Introduce 25 cc. of the freshly-prepared reagent into each bottle, stopper, shake up and let stand in a place not exposed to a strong light. The rapidity with which the reagent is decolorized is the index of the proportion of

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CO present. H_2S causes a similar decolorization, but affords a brown tint due to formation of Ag_2S. The hydrocarbons of illuminating gas probably also decolorize the reagent.

Carbonic Acid in Natural Waters.—Seyler (Analyst, XXII., 312). The author has satisfied himself by experiments given in detail that methyl orange indicator is to all intents unaffected by CO_2 and that phenolphthalein is strictly neutral to bicarbonates, In the latter case, to get trustworthy results, the solution must be sufficient dilute to retain absolutely all CO_2 in aqueous solution.

100 cc. of the water is titrated with N/20 Na_2CO_3, and phenolphthalein indicator. This gives free CO_2. The combined CO_2 may be estimated by titration with N/20 HCl and methyl orange indicator, neutrality to phenolphthalein $CO_2 + Na_2CO_3 + H_2O = 2NaHCO_3$, neutrality to methyl orange $NaHCO_3 + HCl = NaCl + H_2O + CO_2$.

The mode of calculation when the water contains free mineral acid (which of course precludes the presence of bicarbonate) is evident. The presence of ferrous salts requires special modifications, but such cases are infrequent. In upland surface waters CO_2 both free and combined are low. In mixed water from cultivated land, free CO_2 is low, combined CO_2 moderate. In underground waters free CO_2 is usually about 0.5 per 100,000. The amount is closely related to the porosity of the strata. The amount of dissolved O is often correlated to that of free CO_2 varying in inverse proportion. Many natural waters have been found to contain neutral carbonates (alkaline to phenolphthalein). Sea water appears to be invariably so.

In the discussion Mr. A. H. Allen asked whether the author had found any evidence as to the existence of $CaH_2(CO_3)_2$. His reply was in the affirmative, and the results of experiments as to this point were quoted. The solubility of $MgCO_3$ in water was referred to by the author and others.

Sulphates in Potable Waters.—Marboutin (Bull. Soc. Chim. [3], XVII.). Acidulate 100 cc. of the water with HCl, boil out CO_2, add excess 30 cc. of standard $BaCl_2$, let stand to settle. Then neutralize with a little ammonia, and add 30 cc. K_2CrO_4 solution. Cool and make up to 300 cc. In 100 cc. of the clear liquid determine chromate remaining by adding standard As_2O_3 to the solution acidified with H_2SO_4, and titrating with standard I solution after neutralizing with K_2CO_3. No filtration is necessary.

Sulphur in Coal, etc.—Glaser (J. Am. Chem. Soc., XX., 130). Clark asserts that the action of Na_2O_2 on coal and such materials is too violent for use in analysis. The author finds it available in this manner: The material placed in an Ag or Ni crucible is covered with about four times its weight of Na_2O_2 and upon this a piece of NaOH is laid. Heat is applied gently and cautiously until the generation of gas subsides. Then dry Na_2O_2 is shaken over the half fused mass in small quantities at a time, until all the carbon has been burned, when the mass is heated up to complete fusion. Lixiviation and treatment in the ordinary manner then follow. The method is more rapid, and more readily executed than the ordinary alkali and nitrate fusion.

Sulphur in Bitumen.—Peckham (J. S. C. I., XVI., 996). Boiling with fuming HNO_3, with or without additions of KNO_3, of $KClO_3$, or of $K_2Mn_2O_8$, was ineffective. The method of Carius also was found to be useless. The only method found to be satisfactory was intimately

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mixing in a mortar 2 gms. of the bitumen with 16 gms. each of pure dry Na_2CO_3 and KNO_3 and projecting the mixture a little at a time into a large Pt crucible kept at a dull red heat. After complete fusion the mass is dissolved in water, acidified with HCl, evaporated to remove SiO_2, etc., precipitating with $BaCl_2$ as usual.

Commercial Sulphur Chloride.—Le Roy (Rev. Chim. Ind., VIII., 294). 10 to 15 gms. of the sample are weighed into a graduated flask containing a known amount of pure C_6H_6. The flask is then filled to the mark with pure C_6H_6, and after mixing aliquot portions taken. A portion is shaken in a flask with a known volume of standard NaOH (containing 19.37 gms. Na_2O per litre). The flask is then warmed to expel the C_6H_6. When the S is all dissolved H_2O_2 is added, and the mixture warmed to convert all S to Na_2SO_4, and finally boiled. After cooling the excess of NaOH is titrated with standard acid. This determines (by difference) the amount of NaOH which has been used in forming Na_2SO_4 and NaCl with the S and Cl in the sample. A titration of this liquid with standard $AgNO_3$ affords the measure of the NaCl, and the amount of S and Cl originally present may be calculated from the data afforded.

Phosphorus in Steel.—Mahon (J. Am. Chem. Soc., XIX., 792). By using the acidimetric test on the yellow precipitate and working as described, the author claims to be able to determine P in a steel in eight minutes starting with the drillings, if arsenic is not present. The *Molybdate solution* is made by dissolving 100 gms. MoO_3 in a mixture of 200 cc. ammonia (SpGr 0.90) and 200 cc. water. The solution is filtered into 1250 cc. HNO_3 (SpGr 1.2) blowing air through the mixture. (15 cc. ammonia will neutralize 50 cc. of this solution). The standard KOH is standardized on steels of known contents in P determined by gravimetric methods.

Place 4 gms. drillings in a 16 oz. Erlenmeyer flask, containing 70 cc. water and 20 cc. HNO_3 (SpGr 1.4). Boil until dissolved, then add 3 cc. standard K_2MnO_8 solution and boil until no longer pink, add 10 cc. HCl (SpGr. 1.2), boil until clear, remove from heat when ebullition has nearly ceased, add a mixture of 50 cc. MoO_3 solution and 10 cc. ammonia, mixed just before use. Pour into the middle of the flask. Twirl the flask first in one direction then in another—shake about 15 seconds, filter at once (with pump), wash with cold water. Then place paper and precipitate in a beaker containing excess of standard KOH, add phenolphthalein and determine excess by use of standard acid.

Acidimetric Determination of Phosphoric Acid.—Kilgore (J. Am. Chem. Soc., XIX., 703). A continuation of the discussion on this subject from that in the convention of Association Official Agricultural Chemistry. The chief difficulty with those who tried it was in the slight solubility of the yellow precipitate in water, which makes the washings always acid to delicate indicators. The plan recommended is:

Weigh out 2 gms., incinerate if necessary. Dissolve in aqua regia, make up to a volume of 200 cc. For low percentages (under 5) use 40 cc. of this solution, for a higher percentage (5 to 20) use 20 cc. and for percentages over 20 use 10 cc. Add 5 to 10 conc. H_2NO_3, nearly neutralize with ammonia. Heat on water bath to 60–65° C., add 50 cc. freshly-filtered MoO_3 solution for each 0.1 gm. P_2O_5 presumably present, and digest on water bath for ten to fifteen minutes. Decant the clear liquid on to the filter, wash twice by decantation with HNO_3 of 60 per

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cent., using about 50 cc. of 3 per cent. NH_4NO_3 or KNO_3 solution, transfer to filter and wash 5 or 6 times with water, using 150 to 250 cc. Rinse contents of the filter back into the beaker, add measured amount of standard alkali (excess), then phenolphthalein and titrate back with standard HNO_3.

Insoluble Phosphorus in Iron Ores.—Mixer and Dubois (J. Am. Chem. Soc., XIX., 615). In some ores boiling in HCl (SpGr, 1.10) for 30 to 60 minutes leave some P_2O_5 in the insoluble residue. The method of extracting and determining this "insoluble" P_2O_5 was found to be most expeditiously and accurately accomplished thus:

Treat about 1.5 gms. of ore with 25 cc. HCl (Gr 1.10), evaporate to a syrup. Dilute and filter, dry and ignite the residue. Break up the ash with a glass rod, and ignite for a few minutes, and then boil the residue with HCl or HNO_3 for about 5 minutes. Filter and in the filtrate determine P_2O_5 in the usual manner.

An examination of insoluble residues from ores of this character seemed to indicate that the insoluble phosphorus was combined with Al_2O_3.

Determination of the Phosphoric Acid as $Mg_2P_2O_7$.—Lasne (Bull. Soc. Chim., XVII., 823). The conclusions are: 1. This method of determining P_2O_5 (with addition of citrate) without other preliminary except removal of SiO_2 is attended with no essential error.

2. Rapid precipitations cause a partial formation of $Mg_3(PO_4)_2$ which does not become transformed to $MgNH_4PO_4$ except by contact for 16 hours with $(NH_4)_3C_6H_5O_7$ of sufficient concentration (10 gms. of citric in 150 cc. of solution). The precipitation should stand over night.

3. Nevertheless the difference is not sufficient to require a rejection of rapid method if a proper allowance is made.

4. The transformation of $Mg_3(PO_4)_2$ into $MgNH_4PO_4$ is very slow in presence of NH_4Cl only. Citrate should always be added.

5. Precipitation of $MgNH_4PO_4$ (to determine MgO) in presence of an excess of phosphate is always accompanied by a phosphate poorer in MgO, which is larger the greater the excess of phosphate. Determinations of MgO by this method are, therefore, always inaccurate.

Estimating Nitrites.—Grützner (Arch. Pharm., CCXXXV., 241). 0.1 or 0.2 gm. of the nitrite is dissolved in 500 cc. of water, to which is then added 0.5 gm. $KClO_3$ and a known amount of N/10 $AgNO_3$ and HNO_3 to strong acid reaction. The mixture is then well shaken. The reaction occurring is: $3HNO_2 + HClO_3 = 3HNO_3 + 3HCl$. The excess of Ag is then determined by titration with standard NaCl solution. 1 cc. N/10 $AgNO_3$ = 0.0142 gm. HNO_2 or 0.0114 gm. N_2O_3. By diluting 5 cc. of fuming nitric acid to 750 cc., and similar treatment, the N_2O_4 present may be determined.

$$1 \text{ cc. N/10 } AgNO_3 = 0.0276 \text{ gm. } N_2O_4.$$

Commercial Sodium Sulphide.—Jean (Ann. de Chim. Analyt., II., 341). 10 gms. of the sample are dissolved in water and filtered, the FeS being determined in the insoluble portion. The filtrate is made up to 1 litre, of which 10 cc. are titrated by standard I, with starch indicator to determine *total sulphur*. Another 10 cc. are distilled, with addition of $(NH_4)_2SO_4$, the distillate being received in 2 cc. of N/10 acid. After boiling the distillate to expel H_2S it is titrated back with N/10 alkali. The acid neutralized by the NH_3 from the distillation is calculated to

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Na_2S. The residual liquid in the retort is cooled and titrated with N/10 I, which gives $Na_2S_2O_3$. The difference between this and the determination of total sulphur is *calculated* as Na_2S. Deducting from this the Na_2S determined by $(H_4)_2SO_4$ distillation gives *free sulphur* in terms of Na_2S.

Adulterants of Portland Cement.—Stranger and Blount (J. S. C. I., XVI., 853). Kentish rag stone—a siliceous lime carbonate—acts chiefly as a diluent, though, since it contains a little moisture, it acts in some cases advantageously by slaking free lime, thus taking the place of aëration. But even in that case its diluent action, and consequent deterioration of the product, is the most marked effect.

Gypsum, except to the extent of 2 per cent. to control the setting, is also a harmful adulteration.

Blast furnace slag might seem to be of advantage because it might act as a puzzolana. When granulated this is, to a certain extent, true, but the ordinary slag allowed to cool slowly in masses has no influence in this way. Moreover, in any case the slag always contains sulphide, which is a serious detriment. By its slow oxidation it would produce stresses which interfere with the strength and soundness of the structure in which it may be used.

Iron and Steel.—Carnot and Goutal (Am. de Chim. Analyt., II., 301). The rapidity of solution of the Fe may be increased by placing a Pt disc (perforated) in the bottom of an Erlenmeyer flask, introducing 50 cc. of a 30 per cent. solution of 2KCl, $CuCl_2$, for each gm. of metal to be treated, acidifying with 4 or 5 drops of HCl, then boiling for a few minutes. After cooling to 10° C. the metal is introduced, and the temperature raised to 90° or 95° C. To avoid oxidation, and also to agitate the liquid, a stream of CO_2 should be passed through it. Under these conditions the attack is very rapid. In the residue C and S may be determined by treatment by well known processes; in the case of S oxidation by Br. If P or Cr are to be determined, the Cu solution used should be *neutral.* For P treat with HNO_3 and Br, oxidize carbides by boiling with some CrO_3, then dilute, and proceed with the molybdate separation. For Cr fuse the residue with Na_2O_2, dissolve in water, and conduct the rest of the operations as usual. W and Ti are also left in the residue, if present. For their determination remove SiO_2 by HF, fuse with a mixture KNO_3 and K_2CO_3 (8: 4). Dissolve in water, precipitate WO_3 by $Hg_2(NO_3)_2$. In the residue determine Ti by fusing with $KHSO_4$, reducing with SO_2 and boiling after an addition of $NaC_2H_3O_2$, to separate TiO_2.

Coal Analyses.—Kent (Trans. Am. Inst. M. E., Chicago meeting, February, 1897). Examination of several analyses of coals appears to show that in bituminous coals the fixed carbon is nearly equal to total C minus 5 times the available H ($H - \frac{1}{8}O$), and in semi-bituminous coals it is nearly equal to total C minus 3 times the available H. The ratio of fixed carbon to heating power for each coal deposit seems in a general way each to follow a law of its own. The general trend, however, is in the direction of the Mahler line (average of tests by Mahler calorimeter plotted in a curve).

Bronze and Brass.—Falet (Ann. de Chim., Analyt., II., 383). When Zn and Cu are together in a solution each interferes with titration of the other (Na_2S or KCy). The author proposes as a rapid method titration of both together in ammoniacal solution by standard Na_2S solution, then

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acidifying with HCl and boiling to dissolve ZnS, and after filtering titrating again with Na_2S, the Cu being determined by difference.

Bronze and Brass. Electrolytic.—Hollard (Bull. Soc. Chim., XVII., 886). Dissolve in a mixture of HNO_3 (36° B) and conc. H_2SO_4. Proportions should be

For 1 gm. of alloy	20 cc.	HNO_3	and	6 cc.	H_2SO_4
2 gms.	21 cc.	"		8cc.	"
5 gms.	25 cc.	"		15 cc.	"
10 gms.	30 cc.	"		20 cc.	"

Dilute to 350 cc. and heat to nearly boiling until the insoluble residue (containing some SnO_2) is well granulated. Then in this solution precipitate Cu by electrolysis with the usual precautions. Evaporate the liquid (free from Cu) down until only a few drops of H_2SO_4 are left, take up with HCl and water, precipitate by H_2S, filter and wash with conc. solution of NaCl. Dissolve in yellow $(NH_4)_2S$ solution, evaporate to dryness on the water bath, and take up with 9 gms. $KClO_3$ in solution and HCl. Evaporate again to dryness, take up with 30 cc. HCl and water, add 30 gms. $(NH_4)_2C_2O_4$, dilute to 350 cc., warm up to 90° and electrolyze (current 0.7 amp.). Deposition of Zn is complete in 12 hours.

For Sn heat the filtrate freed from Cu and Sn and evaporate low, take up with water, neutralize with ammonia and add 15 cc. of a 10 per cent. solution of $(NH_4)_3C_6H_5O_7$, 9.4 cc. of glacial $HC_2H_3O_2$ and ammonia to neutrality (or 13.8 gms. $NH_4C_2H_3O_2$ and 5 cc. of glacial acetic. Dilute to 350 cc. Electrolyze with a current of 0.6 amp. for 12 hours, which deposits the Zn. Fe, if present, would come down with the Zn, which must be dissolved up and titrated with standard $K_2Mn_2O_8$. Pb should be determined electrolytically in HNO_3 solution of a separate portion.

Alloys for Metal Bearings.—Garrigues (J. Am. Chem. Soc., XIX., 934). Cu is determined by titration after KCNS precipitation (see above). Sb by Mohr's titration with I in alkaline solution after reduction (Gooch and Gruener, Am. J. Sci., XLII., 233), Pb as $PbSO_4$ filtered through paper in a Gooch crucible. Sn as SnO_2 or in presence of Sb by difference. The residue from treatment of these alloys with HNO_3 is never SnO_2 alone, but may contain besides Sb_2O_4, also Fe_2O_3, P_2O_5, As_2O_5, and small amounts of Cu and Pb. Fusion with $Na_2S_2O_3$ may be used for separation.

As, determined by distillation method. The HNO_3 solution of the alloy should be boiled with a little $KClO_3$ to completely oxidize As, and avoid loss thereof until one is ready to reduce by adding $FeSO_4$ and to distil off $AsCl_3$ with HCl. P. is oxidized up and determined eventually as $Mg_2P_2O_7$.

Solid Matter in the Air.—Cohen (J. S. C. I., XVI., 411). Passing 20 or 30 litres of the air through a zigzag tube smeared inside with vaseline was tried, but the best method was found to be filtering the air through a cotton plug. The increase in weight was determined by weighing the plug, using as a counter balance another cotton plug of the same weight as the original.

Mineral Matter in Rubber Goods.—De Koningh (J. Am. Chem. Soc., XIX., 952). Simple ignition gives inaccurate results. If, however, 5 gms. of the sample are treated in a covered beaker with 50 cc. of fuming HCl for an hour, then heated to 70° C. for another hour, 50 cc. of water

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added, and the insoluble material filtered and washed with boiling water, the mineral matter is practically extracted, and the residue after drying on a water bath and finally for 3 hours at 105° in an air bath, gives rubber less the most of its mineral matter. Ignition of this residue will give the remainder of the ash (in many cases found to be $BaSO_4$).

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF GEOLOGY.

The work of the department has been much more conveniently and satisfactorily done this year than ever before, as the facilities at the new site are far superior to those at the old. A well-lighted and spacious laboratory has been something much needed for years past and is now in daily use. In petrography the lectures are much facilitated by the use of a recently acquired projecting, microscopic lantern in which polarized light can be used. A well-illuminated circle of polarized light, 8 to 10 feet in diameter, can be thrown on the screen, and the field of the microscope, of a quarter-inch diameter, can be magnified to this extent. The instrument was first used in series of three lectures given by Professor Kemp in December, 1897, at the American Museum of Natural History, on the "Development of the Minerals and Textures of the Crystalline Rocks," and was primarily obtained for this purpose.

In addition to the regular instruction in the department, Professor Kemp has been working up his summer notes for the New York state geologist, Professor James Hall. One report will shortly appear and another is partly completed. The field notes taken for the United States geological survey are also being put in shape for a report to the Director. Dr. Hollick has read one important paper on the "Geology and Botany of Block Island," before the New York Academy of Sciences, which will shortly appear in its annals. He is now engaged on further researches upon the fossil plants of the eastern Cretaceous. Dr. Julien lectured on the "Elements of Strength of Building Stones," on March 23d, before the Franklin Institute of Philadelphia.

The department has recently received the following gifts: An elaborate model of the great zinc mine at Franklin Furnace, N. J., constructed by Mr. F. L. Nason, for the Lehigh Zinc and Iron Co. Since the consolidation of the Lehigh Co. with the New Jersey Zinc and Iron Co., the model was presented to Columbia through the kind offices of Mr. August Heckscher. A model of the Black Rock-Niagara silver vein at Butte, Mont., has also been received through the kindness of Mr. W. D. Thornton, recently a special student in the department. The model is constructed of 30 tabular slabs of well-seasoned wood, which, when put together side by side, reproduce the geological feature of the veins. The model recently figured in an important side-line mining suit, that was carried to the United States supreme court. Mr. William E. Dodge has presented us with a fine suite of the copper ores of the Copper Queen mine at Bisbee, Arizona. The suite embraces beautiful masses of malachite and azurite, for which the mine is famous. Dr. A. R. Ledoux has given us several large masses of the tin ore from the Harney Peak mines,

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in the Black Hills. Through Mr. F. H. Knowlton, of the U. S. Geological Survey, the department has received a set of the fossil plants recently described by Mr. Knowlton from the Yellowstone Park. A set of rocks illustrating the geological formations of the Wasatch mountains, Utah, and another from various remote points in northern Wyoming, have been received. The last came from Professor W. H. Knight, of the University of Wyoming. Dr. Heinrich Ries, now Barnard Fellow in the University, has sent to the department a valuable series of specimens illustrating the raw materials and finished products of the foreign regions productive of clays and related materials. To all of the friends, who have in this way remembered Columbia, the department expresses its appreciative thanks.

BOOK REVIEWS.

Elements of Theoretical Physics. By DR. C. CHRISTIANSEN, professor of physics in the University of Copenhagen. Translated into English by W. F. Magie, Ph.D., professor of physics in Princeton University. The Macmillan Company, New York. Pp. 333, with 143 diagrams. $3.25.

This treatise presents the fundamental principles of theoretical physics, or in other words, is a mathematical treatment covering the entire domain of physics. Of course it merely touches upon the salient points, but in so doing furnishes the reader with a comprehensive view extremely useful no matter to what special branch he may later confine himself.

An extremely short introduction in which the author states that in physics it is assumed that all phenomena are capable of ultimate representation by motions prepares the way for the opening chapter on general theory of motion, which is by far the best in the book. The remainder of the subject is then treated analytically under the following headings or chapters: The Theory of Elasticity, Equilibrium of Fluids, Motion of Fluids, Internal Friction, Capillarity, Electrostatics, Magnetism, Electromagnetism, Induction, Electrical Oscillations, Refraction of Light, Thermodynamics and Conduction of Heat.

There is no separate complete treatment of sound. This branch of physics is only touched upon as furnishing examples in the chapter of elasticity under the sections of Wave Motion and Vibrating Strings.

It is doubtful whether in this country there is any considerable body of readers to whom this book will be of much use. It is not sufficiently comprehensive to be used as a reference book by one who has worked much in the subject and it is too condensed and contains too few illustrations and details to be of any great aid to a beginner. Nevertheless, we realize that there is need of a book which will enable us to get a birds-eye view, as it were, of the whole subject, using a consistent notation throughout and showing how the various branches are related to each other. T he task set himself by the author in attempting to condense his survey into such a narrow compass, is a very difficult one, and, bearing that in mind, the result produced is certainly admirable.

W. H. F.

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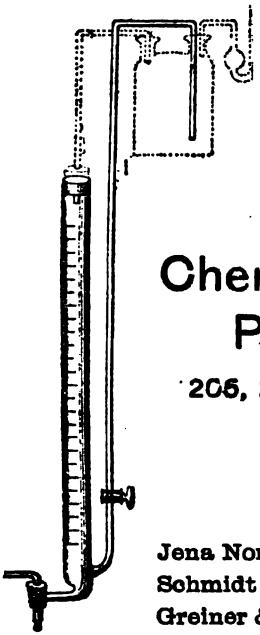

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CONTENTS:

The Heating and Ventilating of Columbia University, by G. A. Suter, 329
Liquid Air, Its Production and Properties. By Samuel A. Tucker, Ph.B., F.C.S. 344
Between the Mine and the Smelter.—A Lecture delivered before the Graduating Class of the School of Mines. By Albert R. Ledoux, A.M., M.S., Ph.D. 358
An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D. 374
The Ballistic Galvanometer, and some of its Applications. By W. H. Freedman, E.E. 392
The Assay of Telluride Ores. By Charles H. Fulton 419
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph.D. 427
Alumni and University News 438
Book Reviews 440
Plates for "The School of Architecture in its New Quarters." By William R. Ware 441

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XIX. JULY, 1898. No. 4.

THE HEATING AND VENTILATING OF COLUMBIA UNIVERSITY.*

BY G. A. SUTER.

It would be very difficult to give an intelligible description of the various blowers, motors, heaters and other appurtenances which comprise the heating and ventilating apparatus of the Columbia University Buildings without the use of photographs or steriopticon, which are not at hand. It is my purpose, therefore, to confine my remarks to an explanation of the theory of the heating and ventilating apparatus, explaining or describing only such details as are necessary to a proper understanding of the subject, leaving you to personally examine the machinery in the various buildings, by which the results described are accomplished. This can no doubt be seen at any time, and whenever you have a few hours to spare, you can, by your own observation, learn more that you will remember about the practical operations of the apparatus than I can possibly tell you; my explanation will only help you to understand its purpose.

I wish to give you, first, a brief description of the several more important methods of steam heating and ventilating with which you are no doubt familiar; but which I wish to present to you in a way that will enable you to better understand the nature of the heating and ventilating apparatus we are about to discuss, and also its general appropriateness for the Columbia University Buildings.

I wish to call your attention, first, to the simplest and the most generally adopted method of steam heating, that known as "Direct

*A lecture delivered before the Engineering Society of Columbia University.

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Radiation," in which the radiators, coils or other heating surfaces, which warm the rooms, are located directly in the rooms. Steam is generated in a boiler in some other portion of the building or grounds, and is conveyed through a system of steam-supply pipes to the radiators in the various rooms, in which the steam is condensed, thus giving up the latent heat of vaporization, and then the condensed steam or water flows back to the boiler through a system of so-called return pipes either by gravity or by the assistance of pumps or other mechanical means.

Suppose that all the windows and doors of this room are closed, also the air-supply registers and the exhaust registers, and suppose that the air in this room is at a temperature of 70° while the external temperature is zero. Suppose now that there is no heating apparatus in the room, then the air in the room will cool gradually, the heat in the air being absorbed by the exterior walls and windows and transmitted to the outer air until equilibrium is established and the inner and outer temperature are the same. Every room or apartment loses heat in this way by conduction through the outer walls, windows, floors, ceilings, etc. We know the constants or coefficients by which we quite accurately calculate the amount of heat that is so transmitted or lost, and we also know the amount of heat given out by various styles of heating surfaces. The direct radiating surface in the room must, with these data, be so proportioned that the amount of heat given out by the radiators shall be equal to or somewhat in excess of the amount of heat transmitted through walls, windows, etc., in coldest weather.

Direct radiation is the most efficient and economical method of steam heating. It has, however, one great defect, and that is, that when a system of direct steam heating is proportioned so that it will be capable of warming a room in zero weather, it is much too ample for warming the room in ordinary winter weather. This is due to the fact that the amount of heat given out by a steam radiator is practically a constant quantity, the same in warm weather as in cold weather, while the amount of heat necessary to warm the room varies in direct proportion to the difference between the interior and the exterior temperature, so that a radiator of sufficient size to heat the room to 70° in zero weather is twice as large as is necessary for warming the room to 70° when the outside temperature is 35°. The regulation by hand of a direct system of steam heating is very difficult, as the turning on or off of valves is

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usually attended to by the occupants of the room only after a certain amount of discomfort, either from heat or cold, has been experienced, and the temperature of the room will vary through wide ranges and, therefore, an automatic device is necessary to secure close regulation.

In describing to you the method of direct radiation, I have assumed that the doors and windows and also the registers, if any, are closed, and this assumption points out to you that direct steam heating provides for no ventilation whatever, and in cases where it is desired, not only to have heat, but at the same time to have a supply of fresh air, we use the second method of steam heating, that known as "Indirect Radiation." In this system the radiator or coil which warms the room is located outside of the room, usually in the cellar below, where it is encased in an enclosure of sheet metal, brick or other suitable material, and cold, fresh air is brought to the radiator or coil, warmed, and then passed through vertical flues and registers up to the various rooms. The air entering the room must be heated to a temperature higher than that at which the room is to be kept, and the mixing of the warm air coming in with the cooler air already in the room maintains the temperature at the desired point. Having brought the supply of fresh air into the room, it is necessary also to provide a means of taking an equal quantity out, which is usually done with ventilating or exhaust flues, extending to the roof of the building. Now while this method of heating provides for a supply of fresh air and for the removal of the vitiated air, it is also defective in that the supply of fresh air and the removal of the vitiated air varies in quantity according to the differences between the inner and the outer temperature; the less this difference of temperature the less will be the amount of ventilation, so that when the interior and the exterior temperature are nearly equal there is practically no ventilation. It is also a defective system in that it requires the shutting off of the fresh-air supply whenever the room is warmer than is required.

An indirect system of heating is more expensive in the consumption of fuel than a direct system. In the latter all the heat given out by the radiators is utillized directly in warming the air in the room, and theoretically there is no waste. Of course, this condition is not practically attainable, as there is always some leakage of air in or out of the room through doors, windows, etc.,

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but the theoretical efficiency of a direct steam heating apparatus is 100% and practically very nearly approaches this. On the other hand, an indirect heating system is subject to the constant waste of the amount of heat contained in the air which passes out of the room through the ventilating or exhaust flues. A given amount of cold air is taken from out of doors at the outer temperature and a corresponding amount of air is expelled from the room at the inner temperature, and the difference between these two quantities of heat represents a waste, and this waste represents the exact cost in heat of a ventilating system, the amount of heat which escapes through the ventilating flues being the price paid for the ventilation. The efficiency of an indirect system is in many cases as low as 25% and seldom higher than 50%; thus, when the object of the system is to secure heat, it is uneconomical, and when the object is to secure ventilation its results are not uniform or reliable.

In order to overcome the defects of an indirect system, where ventilation is the primary object, a third method of indirect heating or ventilation has been devised, in which the motive power is a fan or blower, capable of forcing into the building the required amount of fresh air and expelling at the same time an equal amount of vitiated air without regard to the temperature conditions. The air so introduced must be heated by coils. This system, known as a "Mechanical System," is sometimes purely a ventilating system, not used for heating, and in such case the fresh air is heated only to the temperature of the room or slightly higher.

In a system in which the building is warmed and ventilated by means of a blower or fan, the same ventilating flues which are used in an ordinary indirect system must be provided for the escape of the vitiated air, and sometimes, instead of using the motive power or fan for forcing the air into the building, the fan is used for exhausting the air from the building, while the fresh air is allowed to enter as in ordinary indirect radiation. This gives us two methods of heating and ventilating a building by means of fans; the one being generally known as the "Plenum System" and the other as the "Exhaust System." As a general rule it may be said that the Plenum System is to be preferred to the Exhaust System, because in the Plenum System the tendency is to make the pressure of the air within the building slightly higher than the barometric pressure outside, and thus in a measure draughts from windows, doors, etc.,

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are neutralized; whereas in the Exhaust System the tendency is towards a slight reduction in pressure, and draughts from windows, doors, etc., are aggravated by this. It may be said that the Exhaust System should be preferred only where there are special conditions which demand such a system.

The ideal system, however, is that in which both the Plenum and Exhaust Systems are combined, fans or blowers forcing fresh air into the building and exhaust fans drawing the vitiated air out of the building.

In order to secure economy of fuel and attendance in heating, ventilating and lighting a group of buildings like the Columbia University Buildings, it is necessary, first, to generate all the steam for heating, ventilating, lighting, pumping and for other purposes, at one central point from which it may be distributed to the various buildings where it is to be used. It would not do to have a separate boiler or generating plant in each building. The Power House in the University Hall contains the boiler plant, the electric lighting machinery, the pumping machinery, and from this power house the steam for heating and for ventilating, and the electricity for lighting and power, and the compressed air for other purposes, are distributed to the various buildings through a system of tunnels connecting the buildings with the power-house. The total present boiler capacity in the power house is about 2000 horse power. It is intended that the total power in the future shall be upwards of 4000 horse power.

In selecting a method of heating and ventilating the various buildings it was necessary to select one that would be both economical and efficient while in use. The heating of the buildings is a necessity during the entire week, including nights and Sundays. It would not be proper to allow a large group of buildings like these to cool off at night because of the apparatus and other things which would be injured by cold and dampness. It is the intention to keep the buildings warm day and night and also on Sundays, and to secure economy, therefore, it was necessary to heat the buildings by direct radiation, that being, as I have told you before, the most economical method; on the other hand, the ventilation is required only at such times as the buildings are occupied by a considerable number of people, usually during only about eight hours per day, and not at all on Sundays, so that the requirements of the heating system and the ventilating system are

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quite separate and distinct. It should be possible to shut off or stop the ventilation in any building or room and still maintain that building or room at a proper temperature, and it should likewise be possible to shut off the heating apparatus entirely without in any way affecting the ventilation. The ventilating apparatus is started in the morning and shut down in the afternoon, while the heating apparatus continues its work without interruption at all times. Radiators have been placed throughout the various buildings under the windows because the windows are the most considerable sources of cold. In a room like this, in which the window area is considerably smaller than the wall area, it is, nevertheless, a fact that the amount of heat passing out through the windows is more than twice as great as the amount of heat passing out through the walls. Placing the radiators in front of windows places the source of heat immediately at the source of cold, and, therefore, increases the efficiency, as the cold is counteracted before it passes into the room.

The ventilation is furnished by a Plenum System of fans, which forces the air through various ducts and flues into each of the rooms, and a corresponding system of Exhaust ventilation, which extracts the air from the various rooms and discharges it at the roof. The blowers and exhaust fans are driven by electric motors; the incoming air is warmed by means of indirect heating stacks to 70°, which is the temperature of the rooms, or slightly above that temperature in very cold weather, but the intention is that the air entering the rooms shall be heated to a sufficient degree only to avoid the unpleasantness of draughts and at the same time not produce an appreciable effect on the heating. It is intended that it should never be necessary to shut off the ventilation in order to prevent excessive heating, the regulation of the heating being accomplished solely by means of an automatic system of heat regulation which controls the direct radiators.

In the Library Building the fresh air is brought down from the roof of the building through a fresh air shaft and is then forced by four Sturtevant blowers, each eight feet in diameter, through four heating stacks or coils which warm the air to the required temperature and are controlled by an automatic heat regulating system. From these heater coils the air is forced into the underground conduit, fresh-air duct or plenum chamber, which entirely surrounds the central portion of the Library Building, and from

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this conduit the various ducts and underground branches convey the air to the vertical fresh-air flues, which deliver the air through registers in the various rooms. The underground conduits in the Library Building are made so large that a uniform pressure of air is maintained throughout, while the connections between the underground conduits and the vertical flues are reduced in area to a sufficient extent to make these connections the principal resistance to the flow of air, and in this way an absolutely uniform distribution of air through all the flues is secured and maintained at all times. The exhaust ventilation in the Library Building is effected through vertical ventilating flues extending from the various ventilating registers down to the cellar where the ventilating flues are all joined together by a system of conduits and ducts corresponding generally in size and distribution to the conduits and ducts for the fresh-air supply, already described, and out of these conduits four Sturtevant exhaust fans, which are seven feet in diameter, exhaust the air and force it up through the foul air shaft to the roof. The method of regulating the flow of air so as to make it uniform in all the flues is the same for the exhaust system as that described for the fresh-air supply system, by a reduction of area in the connections between the underground conduits and the vertical flues. The four eight-foot diameter fresh-air fans and the four seven-foot diameter exhaust fans are arranged in four groups, each group containing a fresh-air fan and an exhaust fan and each group being driven by a 25-horse-power electric motor, Crocker-Wheeler pattern, arranged so that the fans may be run at several speeds. As the speeds of the fresh-air fans and the foul-air fans are thus the same, and as the former are of greater capacity than the latter, at the same number of revolutions the amount of fresh air forced into the building is in excess of the amount of air exhausted, and the purpose of this is to secure a slightly greater internal pressure of air, so that any leakage of air through doors or windows shall be outward rather than inward.

The systems in the other buildings are very much the same as that in the Library Building. In each building there are at least two fans, driven by one or two motors, which force the air into the building through underground or overhead ducts to the various vertical flues and registers and into the different rooms, the same as in the Library Building, using Sturtevant blowers or fans and Crocker-Wheeler motors. The exhaust ventilation is accomplished in a

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slightly different manner; instead of bringing all the foul air down to the cellar to exhaust fans and then forcing it up again through shafts to the roof, all the ventilating flues from the various rooms are taken directly to the attic of the buildings and there carried through a system of sheet-metal ventilating ducts to exhaust or disc fans, of the Blackman pattern, driven by direct-connected C. & C. electric motors, these fans discharging the foul air direct through openings in the roof out of doors.

What I have stated regarding the excess of fresh air forced in over the amount of foul air exhausted holds true of all the buildings, excepting the Chemistry Building, in which it was necessary to provide not only for the usual amount of exhaust ventilation, but also for the ventilating of numerous hoods or rooms in which odors and noxious gases are generated; this necessitated a proportionately larger amount of exhaust ventilation than that required in the other buildings.

In the University Hall Building there is also a separate system of fresh-air supply for the power house, which differs from that in the other buildings in that the air supplied to the power house is supplied at the outside temperature without being warmed, the object of this air supply being to cool the power house.

You will notice in this lecture room and throughout these buildings that the fresh-air-supply registers are located at a distance of eight feet or more above the floor level. This location is selected for the purpose of avoiding direct draughts upon persons sitting or standing in front of them, such as would be experienced if the supply registers were at a lower level.

On the other hand, the exhaust registers are placed near the floor, and we are permitted to do this because an outward movement of air through a register is almost imperceptible at a very short distance from it. It was at one time a general belief that the carbonic acid gas, which is one of the principal products of respiration and which is heavier than air, settled in a layer or stratum at the bottom of the room, and, therefore, it was the custom to place the exhaust registers at the floor in order to take out the carbonic acid gas and leave the purer air in the room. Although this theory resulted in the correct placing of the registers, the object sought for was not obtained because the carbonic acid gas was diffused uniformly through the air in the room. On account of the principle of the diffusion of gases, carbonic acid gas and

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the other products of respiration are present in almost uniform quantities throughout any room, and not more at the floor than at the ceiling. The ventilation of a room consists in keeping the percentage of impurities in the air at as low a point as possible, not in eliminating them altogether, so that from the standpoint of ventilation the exhaust registers may be located at any level required by other conditions, architectural or otherwise. One motive for locating them near the floor, or the condition which requires this location, is the satisfactory heating of the room. If the exhaust registers were near the ceiling, then the heated air, as quickly as it comes from the radiators, would be drawn out of the room, and the heating of the room would not only be unsatisfactory, but might even be a failure, and these registers are, therefore, placed near the floor, not because that position best suits the ventilation, but because the satisfactory and economical heating of the room requires it.

The steam supply for these buildings comes from the power house through a system of high-pressure pipes, and at this pressure it is used for operating the pumps which return the water of condensation from the heating apparatus to the power house. In each building there are separate pumps, always in duplicate, for pumping back the water from the indirect stacks and from the direct-heating system. These pumps are automatically controlled by pump governors, which are floats operating steam valves on the steam-supply pipes of the pumps, so that the speed of the pumps is automatically regulated by the amount of steam condensed by the heating and ventilating systems, and both are kept free of an undue accumulation of water, which is pumped back to the power house as fast as it is condensed.

The steam used for heating in the Library and in the University Hall is the exhaust steam from the electric engines and pumps in the power house, which, at a pressure of about five pounds per square inch, is supplied to both buildings from these engines. The exhaust steam coming from an engine has given up only that small portion of its total heat which is the equivalent of the mechanical work performed by the engine, and still possesses very great value for heating. There is sufficient exhaust steam, which would otherwise be wasted, available for heating these buildings, so that the Library and the University Hall are heated practically without cost of fuel. Assuming that the cost of fuel is chargeable

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to the electric plant for the generation of light and power, the heating and ventilating of these two buildings is secured without cost; or if we charge the heating and ventilating apparatus with the cost of fuel, then the electric current and pumping of water, etc., is secured without cost. In any case, when all the exhaust steam is condensed in heating or ventilating apparatus, we have the greatest possible economy of fuel, as there is then absolutely no waste.

As it is expected that all the exhaust steam from the power house can be condensed in these two buildings, the other buildings are supplied with steam for heating and ventilating directly from the high-pressure pipes coming to them from the power house. But this high pressure steam is also reduced to low pressure, less than ten pounds per square inch.

We use low-pressure steam in preference to high-pressure steam in heating. It has a lower temperature, thus making the heating surface or radiator less dangerous when we happen to come in contact with it; it is less dangerous in case of a break or explosion; it imparts a milder temperature to the air; it gives up a greater quantity of its total heat and is, therefore, more economical; and it also permits the admixture of the the exhaust steam from engines and pumps.

The high pressure of the steam is reduced to low pressure in each building by means of automatic reducing valves or pressure regulators, which are valves that throttle the steam by compelling its passage through small openings, the area, and the opening and closing of which, are controlled by the pressure of the steam in the low-pressure pipes. These reducing valves are capable of adjustment, so that any desired pressure may be automatically maintained.

The automatic control of the steam pressures, the automatic return of the water of condensation to the power house, the automatic control of the electric motors which drive the blowers and fans, and the automatic control of the temperature of the fresh air and of the separate rooms, all reduce the cost of attendance to a minimum. All pipes, throughout the tunnels, throughout the cellars, in all recesses, in all walls and everywhere, as well as all fresh-air ducts made of sheet metal, are covered with non-conducting material to save heat and fuel. These factors, coupled with the saving resulting from the use of the exhaust steam, produce a heating

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and ventilating apparatus which is as economical as it is possible to make it. But notwithstanding all these precautions to secure economy, it is nevertheless expensive to operate this heating and ventilating apparatus, because, as I have told you before, any attempt at ventilation means a corresponding waste of heat, and much ventilation means much waste of heat, and this waste is inseparable from ventilation.

I have prepared a table to illustrate what I have already told you, as follows:

1	2	3	4	5	6	7	8
Buildings.	Cubic Contents in cubic feet.	Direct Heating Surface in square feet.	Quantity of steam condensed in Direct Heating System in Zero weather expressed in Standard Horse Powers.	Fresh-Air Supply per hour in cubic feet.	Quantity of steam condensed in Ventilating System in Zero weather expressed in Standard Horse Powers.	Power of Electric Motors expressed in Standard Horse Powers.	Total Power in Zero Weather.
Library.	2,100,000	12,000	120	8,220,000	400	100	620
Physics.	600,000	4,600	45	2,580,000	125	40	210
Nat. Science.	1,250,000	8,500	85	6,000,000	300	80	465
Chemistry.	1,400,000	10,400	105	5,760,000	300	95	500
Engineering.	600,000	5,500	55	3,000,000	150	40	245
Univ. Hall.	3,750,000	15,000	150	21,600,000	930	280	1510
Totals.	9,700,000	56,000	560	47,160,000	2205	635	3550
Room No. 3.	30,000	350	3½	180,000	9	2½	15

Column 1 gives the names of the Buildings.

Column 2 gives the cubical contents of each building expressed in cubic feet.

Column 3 gives the direct heating surface in radiators, coils, etc., in each building, which is calculated to be sufficient for warming it to 70° Fahrenheit in zero weather.

Column 4 gives the quantity of steam which this direct radiating surface will condense in zero weather, expressed in standard horse powers. When the outside temperature is higher the quantity of steam condensed will be correspondingly less. This

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saving of steam when the weather is milder is secured only by reason of the automatic temperature regulating system.

Column 5 gives the total quantity of fresh air supplied to each building in cubic feet per hour.

Column 6 gives the quantity of steam expressed in standard horse powers, condensed in the indirect heater stacks in zero weather, necessary for heating the above quantity of fresh air per hour from zero to 70° Fahrenheit. When the outside temperature is higher the quantity of steam condensed will be correspondingly less.

Column 7 gives the power consumed by electric motors, in driving the blowers and exhaust fans by which this air supply is secured, in horse powers.

Column 8 gives the total power employed for all purposes in zero weather; for direct heating, for ventilating and for motors, when the specified results are obtained.

This table is approximate only, but sufficiently accurate for our purpose. You will notice, that, by comparing columns 3 and 4, for each one hundred feet of radiating surface we require the equivalent of one horse power of steam, or, in other words, each one hundred square feet of radiation will condense that much steam in zero weather. This affords you an easy and rapid method of estimating the required boiler capacity for a direct steam-heating apparatus, making, of course, due allowance for other contingencies. Likewise, by comparing columns 5 and 6, you will notice that for each 20,000 cubic feet of fresh air supplied per hour, we require one horse power of steam to heat that quantity of air from zero to 70° Fahrenheit, the temperature at which it is introduced into the room. Further, by comparing columns 5 and 7, you will notice, for each 75,000 cubic feet of fresh air supplied and exhausted per hour, we require in motive power or mechanical energy approximately one horse power. Now, in order to give you a tangible measure by which you can get at an idea of what these figures mean, I have given in the last line of the table the data relating to this lecture room. The total cubical contents of this room are 30,000 cubic feet; the total direct radiating surface in the room is 350 square feet, and the total steam consumption or proportionate boiler capacity required for the heating of this room in zero weather is 3½ horse power. The moment, however, that you ventilate this room, renewing or replacing the air six

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times each hour, supplying 180,000 cubic feet of fresh air per hour, we require not less than nine horse power of steam, when the outside temperature is at zero, to warm this quantity of air from zero to 70° Fahrenheit or room temperature, and in addition thereto, 2½ horse power for the mechanical effort required to move this quantity of air in and out of the room. Therefore, out of the total of 15 horse power that are required for the heating and ventilating of this room, only 3½ horse power are required for heating, while 11½ horse power are required for ventilation. Similarly, out of a total of 3550 horse power required for warming and ventilating these buildings in zero weather, only 560 horse power are required for the direct heating, while 2990 horse power are needed for the ventilation. When the outside temperature is higher these quantities are correspondingly less, except that the motor power, of course, remains constant. For example, at 35° outside temperature, out of a total power of 2017 horse power, the direct heating requires 280 horse power, the ventilation 1102 horse power for heating the air, and 635 horse power for motive power, or 1737 horse power for both. The proportionate amount of power for the ventilation, as compared with the total power, increases as the outside temperature increases, and, as our average temperature during the heating season is not far from 35°, it is fair to conclude that the ventilation of these buildings costs about six times as much as the heating.

This gives us a clear illustration of the cost of ventilation, and an explanation of why, even when the apparatus is provided, the ventilation is somewhat curtailed. We sometimes wonder why our public buildings are not better ventilated, but the explanation, when it is not due to ignorance or incapacity, is found in the expense of the apparatus and in the expense of operation.

In these six buildings we have a total cubical contents of nearly ten million cubic feet; we furnish and remove each hour nearly fifty million cubic feet of air, and require in zero weather about 3500 horse power for heating and ventilating. As I have told you before, the total boiler capacity now in the boiler house is about 2000 horse power, so that even here the ventilation may have to be curtailed in extremely cold weather. Fortunately, however, zero weather is quite rare in New York, and when it does come, we usually do not notice slightly deficient ventilation; we are more anxious to get heat, and for the want of this you will never suffer.

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I have brought with me a model of the Johnson temperature regulating apparatus, which is employed throughout these buildings to maintain a constant temperature in the fresh-air supply and also in each individual room. If you will look at the radiators you will notice that each one is provided with peculiar valves which cannot be controlled by hand. They are controlled by compressed air, the application of pressure closing the valves and the relief of the pressure permitting their being opened by metallic springs. The pressure is applied to a flexible rubber diaphragm which presses on the stem of the valve, and when this pressure is released the metallic spring raises the stem and brings the flexible disc back to its original position.

The so-called thermostat which you see on the wall is a device for controlling the supply of compressed air, connected by piping with a compressed air tank in the power house, and with the steam valves on the radiators. The thermostat, by means of a three-way valve, admits the pressure to the radiator valves when the temperature of the room rises to the desired point, and thereby shuts off the steam supply, while, when the temperature falls, it releases the pressure and steam is turned on again.

The motive power for the three-way valve is also furnished by compressed air. There is a small air chamber, one side of which is an elastic diaphragm. To this air chamber there is a minute air supply from the compressed-air piping and also a minute air escape to the atmosphere. There is also a U shaped thermostatic strip, made of two metals, brass and steel, practically a metallic thermometer, which is so sensitive to variation of temperature that when the temperature falls less than one degree below the normal, this thermostatic strip closes the minute air escape, the air chamber is inflated, and the elastic diaphragm moves the three-way valve, so that the compressed air escapes from the radiator valves and steam is turned on. Similarly, if the temperature rises above the normal less than one degree the thermostatic strip opens the minute air escape, which permits a set of springs to move the three-way valve into the other position, which admits compressed air to the radiator valve and shuts off the steam. These thermostats may be set at any desired temperature, and the maximum variation from the desired temperature, when the thermostatic apparatus is well adjusted, is one degree.

In the Columbia University Buildings they are used for turning

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on and shutting off steam at the indirect heating stacks, so that the air supply to the Buildings shall be of uniform temperature, and also for turning on and shutting off steam at the radiators, so that a uniform temperature is maintained in each room.

They may also be used for controlling dampers in air ducts, as, for example, where there are two ducts, one supplying warm air and the other supplying cold air, both connected to the same vertical flue and room.

The thermostats can be employed to control dampers in these ducts, so that either warm air or cold air is admitted to the room according to its temperature, which is maintained at a constant point. Such a system may dispense with the use of radiators entirely, but it is not so well adapted to buildings like these. It is uneconomical when heat alone is desired, and is useful, therefore, only when ventilation is required at all times, or where the need for heat and ventilation always occur simultaneously.

There is only one thing more I want to say to you, and that is, I want to tell you who is the author of the heating and ventilating system in the Columbia University Buildings. I think we have demonstrated that the system does what we claim for it. I think it will work well and satisfactorily, and I have no hesitation in saying so, because it is not my system. The system of heating and ventilation in these buildings was designed and planned by Mr. Alfred R. Wolff, who, as a heating and ventilating engineer, is at the head of his profession, and it has been my privilege to execute practically as perfect a system of heating and ventilating as can be secured in a group of buildings of this character; and I mention Mr. Wolff, because it is only just that I should give to him the credit of having planned what I think will be of so much benefit to you as you go through your college course. I think you will be enabled to do so now without seriously imperiling your health, which was not the case in my time, and the credit for whatever good you will derive from it will belong to Mr. Wolff. I think the College authorities, too, should be credited with having been liberal in the expenditure of money for this purpose. The cost of the heating and ventilating apparatus in these buildings represents a large proportion of the total outlay of money expended on this block, so that to President Low and to Mr. Darling, who had the general supervision of these matters, credit is also due for the appreciation of the importance of this branch of the work.

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LIQUID AIR, ITS PRODUCTION AND PROPERTIES.*

By SAMUEL A. TUCKER, Ph.B., F.C.S.

Researches on the liquefaction of gases have been conducted from the beginning of the present century, and the first gas which was obtained in the liquid state was chlorine.

Northmore, in 1806, succeeded in obtaining liquid chlorine by pressure alone, and shortly afterwards Faraday further investigated the subject and was able to liquefy many other gases, such as ammonia, hydrochloric acid, cyanogen and nitrous oxide. The method adopted consisted in the use of bent tubes of strong glass, one end being filled with a suitable mixture which on being heated produced the gas in question; the other limb of tube was surrounded by a cooling mixture. The gas, by means of the cold and pressure, is in this way reduced to a liquid. In order to reduce a gas to the liquid state two things are necessary, viz., cold and pressure; the particular temperature under which a gas liquefies under a given pressure is called its critical temperature, and the given pressure is its critical pressure.

The gases experimented with by Northmore and Faraday were those whose critical temperatures and pressures were easily obtained, being about zero degrees Centigrade with a pressure varying from one to thirty atmospheres. Such a pressure is easily obtained in the glass tube by the expansion of the gas.

Thus sulphur dioxide is reduced to the liquid state when cooled to zero with a pressure of 1.53 atmospheres, and even at ordinary atmospheric pressure when cooled to $-10°$ C., which may be easily shown by passing dry sulphur dioxide gas through a tube surrounded by a mixture of ice and salt, when it condenses to a colorless liquid. With the means at Faraday's disposal it was impossible for him to investigate the subject much further, but in the year 1833 liquefied carbon dioxide was produced and Faraday continued his researches. Many other gases were liquefied, and he obtained a temperature of $-110°$ C., which was the lowest temperature which had thus far been reached. Many of the gases liquefied by Faraday are still preserved at the Royal Institution in

*From a lecture delivered before the Henry Electrical Society, at Havemeyer Hall, Columbia University, on April 15, 1898.

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London, but there were several gases, such as oxygen, nitrogen and hydrogen, which it was at that time impossible to change to the liquid state, and nothing more appears to have been accomplished until 1877, when the researches of Pictet and Cailletet were brought before the French Academy, on the 24th of December of that year.

These two experimenters worked independently and on totally different lines. Pictet succeeded in obtaining liquid oxygen by means of a complicated piece of apparatus, the low temperature being produced by the rapid evaporation of liquid carbon dioxide. This produced a temperature of —130° C., and in order to accomplish this end he made use of large quantities of liquid sulphur dioxide, which cooled the carbon dioxide to —65°; two powerful pumps were used to compress these gases and keep them constantly in a state of circulation; in this way large quantities of liquid carbon dioxide were produced, which was caused to surround a copper tube supplied with oxygen gas from a strong generator, and by its evaporation lowered the temperature sufficiently to reduce the oxygen to the liquid state, the necessary pressure being derived by the gas itself within the tube.

Cailletet, however, worked on a different principle; his apparatus was much simpler, consisting of a powerful hydraulic press capable of producing a pressure of 1,000 atmospheres.

The oxygen under this great pressure was suddenly allowed to expand, this rapid expansion resulting in a very great lowering of the temperatures of the particles of the gas, the heat being taken up in the act of expanding.

Cailletet succeeded in liquefying both oxygen and carbonic oxide in this way, and it is interesting to note that at the present time the processes for the production of liquid air are based upon this very principle, the necessary cold being always obtained by expansion of a portion of the gas by a sudden dimunition of pressure. The method of applying this principle is changed, however, in the modern forms of apparatus.

It was not until 1883 that much more was done; in this year Wrobleski and Olszewski both succeeded in producing liquid oxygen. These experimenters used apparatus more on a line with Pictet; the low temperature was not produced by the expansion of the gas itself, but by means of boiling liquid ethylene. Their researches were conducted in a very thorough manner, and much of

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our data on the physical properties of matter at low temperatures is derived from their work.

Only minute quantities of liquefied gases were produced, but their investigations cover a very wide range of substances examined, and a careful record was kept of temperatures for all their experiments.

They studied the effect of extreme cold upon substances which had hitherto resisted efforts to be frozen, such as absolute alcohol, which was found to congeal at $-130.5°$ C., and carbon disulphide, which was solidified by a temperature of $-116°$ C.

Besides liquid oxygen they obtained liquid nitrogen and found it to be colorless, and with it they reached a temperature of $-225°$ C. by its evaporation in vacuo. In 1884 they appear to have obtained liquid hydrogen independently.

But up to the year 1890 only small quantities of the so-called permanent gases were produced in the liquid state; thus, in 1884, Olsweski mentions a yield of 6 cc. of liquid air. In 1890, however, Professor Dewar, with much greater facilities, produced liquid air and liquid oxygen in large quantities, and it is to his investigations that we are indebted for the most complete information in regard to researches at low temperatures. These researches were carried on in the laboratory in the Royal Institution.

His apparatus is constructed more after the manner of Pictet, for the cooling agent employed was at first liquid carbon dioxide; later on he made use of liquid ethylene instead. The oxygen to be liquefied is under a pressure of 100 atmospheres, and in passing through coils of copper tubes surrounded by the carbon dioxide is reduced to the liquid state. He in this way produced liquid oxygen, as well as liquid air, in much larger quantities than any previous experimenters. This apparatus, as it appears at present, comprises a powerful gas engine, which gives the power to the pumps for compressing the ethylene, and also the air or oxygen for liquefaction, and the liquefier, which is a coil of copper tube surrounded by boiling ethylene. With this apparatus it is possible to produce a litre of liquid air in about two hours.

The manufacture of the ethylene is troublesome and expensive, as it takes 100 pounds of liquid ethylene for the proper working of the apparatus. This is all made from alcohol and sulphuric acid, and is attended with much danger, besides giving a very poor yield, certainly not over 20%. Dewar's liquefier is shown in Fig. 1

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for use with carbon dioxide. Mr. Charles E. Tripler, in 1890, produced liquid air with an exceedingly simple form of apparatus, and his present plant differs only in size from the one originally introduced. The air is compressed by means of a three-part pump which is operated by a 40-horse-power engine. The first compression is at 60 lbs., the second at 750, and, finally, the pressure is raised to 2,000 lbs. to the square inch. The compressed air, which has now become heated by the compression, passes through a tube surrounded by running water, which takes up most of the heat; it then passes through a filter to the liquefier which is shown in Fig. 2, which consists of a coil of copper tube into which the gas flows. Under a pressure of 2,000

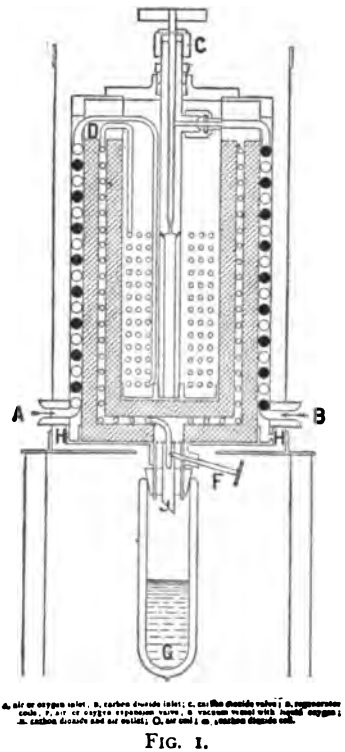

FIG. 1.

FIG. 2.

lbs. a portion is allowed to escape by means of a specially constructed valve through a small opening; the low temperature thus produced easily liquefies the compressed gas within the tube, the liquid air flowing out in large quantities after a short time from the outlet pipe. With this apparatus several gallons of liquid air can be produced per hour.

At Aix la Chapelle it is said they are constructing a plant for the production of liquid air by the Linde system on a large scale, which is to be applied to an improvement in the manufacture of chlorine by the Deacon process, but up to this time Dr. Linde's process, although producing liquid air in considerable quantities, cannot be said to rank with Tripler's. The Linde process is essentially the same, the cold being produced by the expansion of the

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compressed gas through a small aperture, but the best yield appears to be 0.9 litres of liquid air per hour. It will be seen that neither of these processes differ much from that of Cailletet in 1877, although in output they far exceed anything that was then possible.

Gas.	Critical temperature Centigrade.	Critical pressure. Atmosphere.	Boiling point Centigrade.	Freezing point.	Freezing pressure. mm.	Density gas.	Density of the liquid at boiling point.	Color.
Hydrogen.	Below 220	20	?	?	?	1	?	Colorless.
Nitrogen.	— 146	35	— 194.4	— 214	60	14	0.885	"
Carbonic oxide.	— 139.5	35.5	— 190	— 207	100	14	?	"
Argon.	— 121	50.6	— 186.9	— 189.6	?	19.9	1.5	"
Oxygen.	— 118.8	50.8	— 182.7	?	?	16	1.124	Bluish.
Nitrogen monoxide.	— 93.5	71.4	— 153.6	— 167	138	15	?	Colorless.
Methane.	— 81.8	54.9	— 164.0	— 185.8	80	8	0.415	"

Before discussing the properties of liquid air it will be well to draw attention to the following table of constants of liquefied gases, derived mainly from the researches of Olszewski.

It was noticed by Wroblewski in 1884 that in the liquefaction of atmospheric air, its behavior was different from that of a simple and regular gas, and this is what we would naturally expect, in as much as the air is a mechanical mixture of several gases with different boiling points. As it is first formed, unless previously washed by passing the gas through caustic soda, the liquid appears somewhat cloudy, from separation of particles of solid carbon dioxide, but by passing it through an ordinary paper filter we obtain a light liquid, perfectly clear and of a slightly bluish tinge.

On standing in a vessel exposed to the air it at first boils violently from contact with the sides of the vessel, but after a few seconds it remains in a quiet state of ebullition. The nitrogen, having a much lower boiling point than oxygen and argon, naturally boils off first, so that we have a fractional distillation constantly going on, the liquid becoming more and more concentrated in oxygen, and after a short time we have what is essentially liquid oxygen.

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Professor Dewar early noticed the difficulty of preserving liquid air in ordinary vessels, as it soon boiled away by the radiant heat from surrounding objects, and he set himself to work to discover the best means of retaining it. It is quite impossible to store the liquid in metallic cylinders, for it soon exerts a tension which is capable of bursting the strongest that it is possible to construct. Dewar found, however, that it could be retained in a vacuum jacketed vessel for a much longer time than in those which were not surrounded by a vaccuum.

Some of these vessels are shown in Fig. 3, and tests were made in

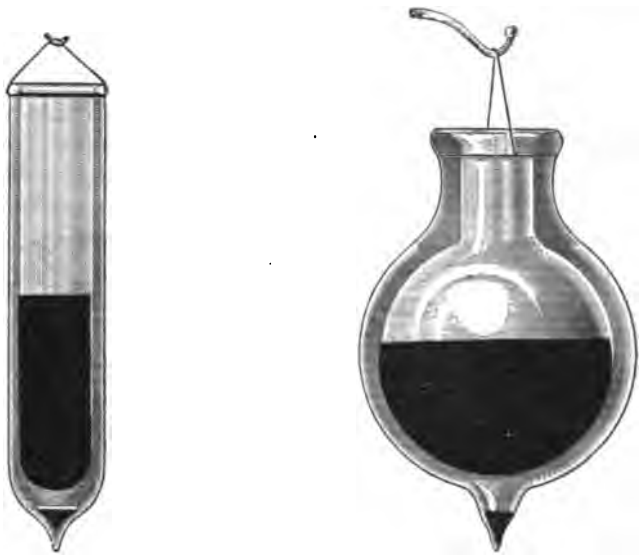

FIG. 3.

order to test their efficiency. This is a very simple matter, as the volume of gas given off in a certain time from the vacuum vessel can be easily compared to the volume from an ordinary vessel; thus he obtained the following results:

Liquid oxygen, vacuum vessel 170 cc. gas per minute.
" " ordinary vessel 840 cc. " "

The next improvement made in the apparatus was in silvering the walls of the containing vessel. It had already been assumed that at the temperature of boiling oxygen a bright metallic coating would be quite transparent to radiant heat. Such, however,

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did not prove to be the case, and when a vacuum is used in conjunction with silvering, we have the most efficient means of storing liquid gases which exists. Many experiments were made to prove this, and it was found that even when a vessel was used which was constructed with three separate vacuum spaces, 60% of of the influx of heat was cut off, as against 96%, using a single-wall vacuum which was silvered.

Such vessels will retain liquid oxygen for many hours, but it gradually boils off even from the best apparatus which can be made. The specific gravity of liquid air is easily shown by pouring some upon the the surface of water contained in a large flask. At first the liquid floats upon the surface, boiling violently, but in a few moments, the nitrogen having boiled away, the oxygen sinks in the water in large spheres which rise and fall, being partly buoyed up by the escaping gas. The specific gravity of liquid nitrogen is 0.885, whereas that of liquid oxygen is 1.124, which accounts for this effect.

The cooling properties of liquid air are among the most striking, for substances immersed in it are reduced to a temperature of at least —182° C., resulting in a complete change of their physical behavior. Rubber or sheet iron are made so brittle that they can be broken like glass by a blow, and a flower exposed to such a temperature has each leaf frozen, still in the form that it originally appeared, but so brittle that the slightest touch crumbles it to pieces. Absolute alcohol is first reduced to a pasty consistency by being brought in contact with liquid air, and gradually changes to a solid. Mercury is, of course, frozen with the greatest ease, and may be cast into ingots of any desired form for experimental purposes in regard to tensile strength.

When the hand is brought in contact with the liquid one would naturally suppose that the flesh would be instantly frozen; such, however, is not the case, because the heat of the hand causes a film of gas to be formed at the surface of the skin, which for a short time protects it. If good contact does take place the result is a severe sore, which generally lasts for several days.

The projection of a jet of steam over the surface of liquid air freezes the gas in a moment, the ice particles falling like a miniature snow storm, and it is, indeed, a sudden transition of temperature, for 901 degrees Centigrade are lost in a moment when we consider that the latent heat of steam is 540°, from water at 100° to ice at zero 179°

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more are lost, and finally that the ice itself is cooled to the temperature of liquid oxygen or —182. The most intense cold is produced by the rapid evaporation of liquefied gases, and liquid oxygen or air may be solidified by evaporating, say, a litre of the liquid in vacua. By the time the volume has been reduced to half a litre the mass has become a solid of jelly consistency, and may be preserved in this way for some time, provided a tolerable vacuum is kept up with a good mercury pump. On exposure the solid air melts almost immediately. Liquid hydrogen may even be produced by first cooling the gas under a pressure of 200 atmospheres by means of liquid oxygen, and then allowing it to expand over a regeneration coil, when a portion of the hydrogen changes to the liquid state, some of which can be collected in a vessel placed beneath. It is difficult to keep it for any length of time, as it boils violently, besides being in a constant state of motion from the force with which it is projected from the coil.

Liquid oxygen, when placed in this liquid hydrogen, instantly assumes the solid form, which is that of a hard, opaque mass. The latent heat of volatilization of liquid oxygen was found by Dewar to be 80 units, and the apparatus which he constructed for the purpose of determining this is shown in Fig. 4.

FIG. 4.

The volume of gas given off by adding a known weight of mercury at a certain temperature corresponds to the latent heat.

It will be noticed from the drawing that the inner tube containing the liquid under examination is perfectly isolated from all external sources of heat by being jacketed with a vessel containing the same liquid, which is in turn surrounded by a vacuum wall.

The same apparatus may be used to determine the specific heat. The inner vessel is this time exhausted by means of a pump to ½-inch pressure; the manometer is then connected by turning the three-way cock and mercury introduced from the reservoir above the inner compartment, until the pressure shown by the manometer

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is the same as that of the atmosphere. From this we know the amount of heat necessary to raise a given quantity of liquid from its boiling point under ½-inch pressure to its boiling point under normal pressure. In this way the mean specific heat of liquid oxygen was found to be 0.39 between —198 and —182. It has been noticed that in the solidification of many organic substances by liquid air, some assume a crystalline form, such as carbon disulphide and carbon tetra chloride, whereas a larger number, as alcohol, turpentine, chinoline, picoline, etc., appear as glassy solids. The addition of a few drops of carbon tetrachloride to alcohol causes it to freeze as a clear solid, and it has been suggested that these properties may be used with advantage for investigation in regard to organic substances. The property of rubber to expand on cooling is well shown by stretching a thin piece of sheet rubber over the wide end of a glass funnel, when, on the application of a little liquid air, the surface will become wrinkled. On resuming a normal temperature the elasticity of the rubber is in no way impaired. Liquid air gives us the means of producing vacua of the highest degree. It is well known that in the production of an ordinary vacuum by means of even the best mercury pumps, there is always some mercury vapor left in the vessel, which exerts an appreciable tension.

If, however, the surface of the vessel is brought in contact with liquid air, the residual mercury vapor is condensed at the point of contact of the liquid air and the vacuum is increased to a remarkable degree. We have taken an ordinary Crookes tube used for X-rays work, and by means of a few drops of liquid air, the vacuum was increased to such an extent that the passage of electricity was entirely prevented, and it can be so arranged that by placing a few drops of liquid air in an indenture of the tube, the discharge will be stopped in the tube, passing between terminals placed at the proper distance outside.

Extreme cold certainly does not stop the subsequent putrefaction of unsterilized organic matter, for Professor McKendrick exposed sealed tubes containing milk, blood and fish to a temperature of —182°C. for an hour, all of which became putrid when brought back to ordinary temperatures. Neither does it prevent chemical action, as the experiment was tried of exposing a rapid Eastman photographic plate in a camera to the same temperature, which, on development, produced a good photograph.

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Dewar found great difficulty in determining the thermal transparency; the glass vessels used affected the results considerably, and the use of rock salt was found to be impractical.

The approximate results, however, are given below; taking chloroform as unity and correcting for differences of refractive index, the numbers indicate the heat transmitted.

Chloroform,	1.0
Carbon disulphide,	1.6
Liquid oxygen,	0.9
Liquid nitrous oxide,	0.93
Liquid ethylene,	0.60
Ether,	0.50

It will be seen that liquid oxygen is almost as transparent to heat as chloroform, which is one of the most transparent liquids.

The capillarity of liquid oxygen was found to be one-sixth that of water; it is also a very high insulator of electricity; so much so is this the case that a discharge, giving a spark gap of 25 millimeters in the air, will only cover a distance of one millimeter in liquid oxygen. Dewar's investigations into the tensile strength of materials at low temperatures is interesting, but was attended with considerable difficulty. The supply of liquid oxygen had to be large, as not only the material experimented with, but the steel jaws of the testing machine had to be immersed in it, as will be seen from Fig. 5. The results obtained are given in the accompanying tables, the tensile strength in most cases having been greatly increased by the cooling.

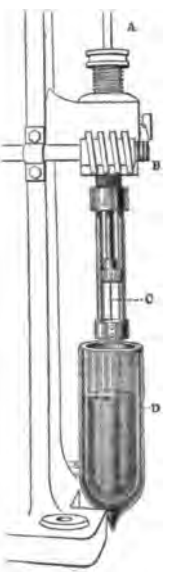

FIG. 5.

Breaking stress in pounds:

	Metallic wires 0.098 inch diameter	
	at 15° C.	at —182° C.
Soft steel	420	700
Iron	320	670
Copper	200	300
Brass	310	440
German silver	470	600
Gold	255	340
Silver	330	420

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Breaking stress in pounds cast:

	Metallic test-pieces 0.2 inch diameter at 15° C.	at —182° C.
Tin	200	390
Lead	77	170
Zinc	35	26
Mercury	0	31
Bismuth	60	30
Antimony	61	30
Solder	300	645
Woods		
Fusible metal	140	450

A good way of showing the increased tensile strength of metals is to cool a spiral of lead wire in liquid air, which retains for some time this property and will support a heavy weight; but as it gradually becomes heated to ordinary temperature the weight falls as the spiral elongates.

The optical effects of liquid air are extremely curious. That it is transparent to both heat and light is easily shown by passing a strong beam from the electric arc through a bath of liquid air, which, on being brought to a focus, easily ignites tinder or paper. It seems, at first, strange to think that the heat rays are passing through a medium from —180 to —190° Centigrade. The spectrum of liquid oxygen is continuous and shows all the absorption bands, and the effect of cooling on certain bodies brings about a remarkable state of phosphorescence and fluorescence. It will be remembered that this property is due to the less refrangible portion of the spectrum than the exciting rays, and depends upon the intensity of the source of light; and what we understand by phosphoresence is the property of emitting a glow for a long time, whereas fluorescence is only continued for a short period. The effect of extreme cold seems to give this property of fluorescence to those substances which do not exhibit it at ordinary temperatures, for substances which are strongly fluorescent or phosphorescent at normal temperatures are completely deprived of this property by being cooled to temperatures far above that of liquid air. Thus calcium sulphide which is phosphorescent at 15° C. is rendered inert by being cooled to a temperature of —80° C., but when heated again it resumes its former activity. Most organic compounds show a bluish green phosphorescence when brought to a temperature of —180° C.; such, for example, are gelatine, India

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rubber, ivory, celluloid and paraffin. The alkaloids also become phosphorescent, and nicotine is rendered more so than either quinoline or pyridin.

Colored salts are often completely deprived of color; such is the case with iodide of mercury. Of the organic bodies those which show the most exceptional powers of phosphorescence are benzo- and aceto-phenon, asparagin and phthalic anhydride; aceto-phenon being the most phosphorescent substance at low temperatures of organic nature, while the platino cyanides exceed all others in the inorganic compounds.*

The refraction index of liquid air for the D ray is 1.2053 and for liquid nitrogen it is 1.2062. Faraday, in his researches on magnetism, used the lowest temperature which it was then possible to obtain, by evaporating liquid carbon dioxide with ether in a vacuum; such a combination gives a temperature of —110°C. But he was unable to give the property of magnetism to those substances which were not already endowed with it; neither was iron made non-magnetic, as he thought might prove to be the case. Liquid oxygen, however, is decidedly magnetic, and its magnetic moment is as 1 to 1,000 as compared with iron. This property is well shown by means of a powerful electro-magnet, whose poles are bent slightly downwards; on putting a small vessel of liquid oxygen beneath, it is actually drawn up, forming a bridge of the liquid between the poles. On breaking the circuit it instantly falls, just as a piece of iron would.

It might be supposed that this property would give a means of separating the constituents of liquid air, by attracting the oxygen away from the nitrogen by a magnet. But it is found that the nitrogen is retained by the oxygen, although in itself it is non-magnetic. Prof. Trowbridge's investigations pointed to the fact that the magnetic moment of a permanent magnet was diminished 50% by cooling to —80°.

Dewar, however, has proved that by cooling to —182° C. and subsequently reheating there is considerable variation in the magnetic moment produced, depending upon the particular magnet used, but that if this treatment is repeated a few times, the results become constant and the magnetic moment is increased to from 30 to 50%. In regard to alteration in electrical conductivity,

* Dewar, Proc. Chem. Soc, 1894, p. 171.

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Dewar and Fleming have carried out an investigation which has led to some important results.

It is easy to show, as we have done for lecture-room experiment, that the effect of cooling results in a diminution in the resistance, by simply using a coil of fine iron wire, which, at ordinary temperatures, allows just sufficient current to pass to produce a moderate glow in an ordinary incandescent lamp. On plunging the coil in liquid air the lamp will glow with the utmost brilliancy.

Experiments were tried by Dewar and Fleming on a large number of metals and alloys and great difficulty was encountered in obtaining metals of absolute purity, for the slightest trace of another metal or of a foreign body affects the results greatly.

The metals used were drawn into wires, from 1 to 2 meters long and from $\frac{1}{12}$ to $\frac{1}{2}$ a millimeter in diameter, which were coiled loosely about a small piece of mica, the connections being made with stout copper conductors. The resistance was determined at five points, viz. :

200° C.
100° C., the temperature of boiling water.
0° C., the temperature of melting ice.
−78° C., temperature produced by combination of liquid carbon dioxide and ether.
−182°, temperature of liquid oxygen.

The temperature was measured by a platinium pyrometer, and the results point to the conclusion that all pure metals become perfect conductors of electricity at the absolute zero of temperature, and a glance at the plotted curves, Fig. 6, show this very graphically.

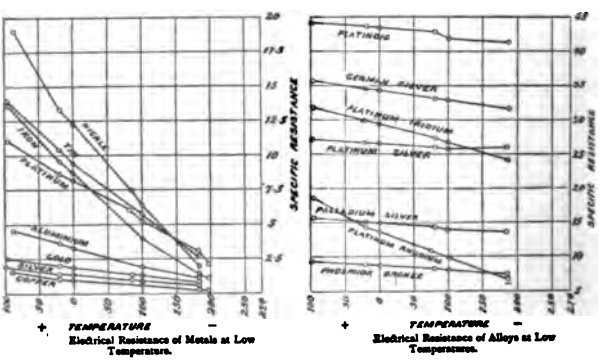

FIG. 6.

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The conductivity of copper surpasses that of silver at low temperatures, and the marked difference in conductivity is apparent if we take two wires, one of copper, the other of iron, and of the same length and thickness which will, at ordinary temperatures, show the iron to have six times the greater resistance, but at the temperature of liquid air it will be found that the iron wire at —186° C. has 30% less resistance than the copper at 15° C.

It is interesting to note that the poorest conductors among the metals are those having the highest atomic volumes together with large valency. The determination of resistance of metals at low temperatures from what has been said in regard to the effect of impurities gives a means scarcely less accurate than the spectroscope for the identification of foreign bodies. In the case of carbon it was found that cooling increased the electrical resistance.

The influence of temperature on the conductivity of alloys is much less marked than with pure metals, as they seem to show a fairly constant temperature coefficient over a very wide range of temperature.

The effects of liquid oxygen in promoting combustion are very striking, a piece of wool or cotton saturated with it burning with the greatest rapidity, and when confined, on being ignited, the explosive force is scarcely less than that of gun-cotton.

A rod of carbon heated to whiteness in the electric arc continues to burn with an intense light when plunged into the liquid, the carbon dioxide actually solidifying around the point as it is formed.

We have here a remarkable contrast of temperature side by side, on the one hand a cold of —182° C. of the liquid oxygen, and on the other carbon raised to a state of incandescence, which is probably not far from 2000° C.

Thus far no industrial uses have been put to liquid air, yet it does not seem improbable but that, when it is made more cheaply there will be many applications to which it can be applied. As a refrigerating medium it may be possible to apply it to the exclusion of all the present systems for the production of cold, for besides producing an excessively low temperature, it adds nothing injurious to the atmosphere on evaporation.

It has already been mentioned that the tension on changing to the gaseous state is so great that as yet no vessels can be made sufficiently strong to stand it, as one volume of liquid air produces 748 volumes of gas, but it is not unreasonable to suppose that a

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way may be discovered by which this power may be utilized. It certainly would necessitate the use of engines of peculiar construction.

From the researches on electrical conductivity there may be commercial applications to which liquid air can be put, as it is to be remembered that at the present day perhaps the largest part of the capital of electrical companies is applied to copper conductors, and if a practical means were discovered for reducing the amount of this copper used, great changes would certainly be brought about in electrical management. From a scientific point of view the production of liquid air gives us a means of inquiry as to the physical states of matter, which opens up a very large field of research of the greatest interest.

BETWEEN THE MINE AND THE SMELTER—A LECTURE DELIVERED BEFORE THE GRADUATING CLASS OF THE SCHOOL OF MINES.

By ALBERT R. LEDOUX, A.M., M.S., Ph.D.

Gentlemen: It is probable that the majority of you upon graduation will seek positions either at the mines or metallurgical works of our Great West or British Columbia, and the course you have taken at Columbia University has amply prepared you to apply practically in the field the instruction here provided. But there are in all professions practical points which can be learned from no book, which are not taught in college lectures, and I have been requested to speak to you this morning as a practical man who has had some twenty years' experience since leaving the School of Mines, in lines of work connected with, or rather *connecting*, mining and metallurgy. I have chosen for my subject: "Between the Mine and the Smelter," and shall discuss it under two heads, the first being general and commercial, and the second specific and technical.

I.

Mr. Walter B. Devereux, one of the most successful of metallurgists graduated from the old School of Mines, has in his lectures supplemented from his large experience what your permanent in-

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structors have told you of conditions necessary to be carefully considered before deciding whether your smelter or mill shall be erected at the mine or at some distant point—questions of fuel, water supply, hauling, etc.

Let us suppose that, as in nine cases out of ten is the fact, you have decided to locate a smelter at a point where fluxes and fuel are more available than at the mine, or to ship your ore to some custom works, at a point so distant in either event that it necessitates railway transportation. The first problem which will usually concern you will be that of freight contracts. There are some railroads, like the Great Northern, for instance, that were built through an almost uninhabited country with the express purpose of building up that country and reaping profits in future, and such roads make very liberal rates to miners and smelters along their lines, as well as to other settlers. But there are other roads primarily built perhaps to secure land grants, or, which run from one populous district to another, almost regardless of grades, and, to some extent, of distance; the longer the distance the more land to be obtained from the government. The policy governing such roads has, generally speaking, been unfavorable to industrial development, unless indeed at points where some of the gentlemen interested in the railroad were interested in the local development.

When my firm began receiving shipments from Montana, in 1880, the freight rates were from $40 to $60 a ton. They probably do not exceed $18 at this time. One of the most conspicuous instances of the separation for economic reasons of works and mines is that of the Boston-Montana Company, in the State of Montana. Their mines are at Butte, and their works at Great Falls, a distance of 175 miles apart, with one of the main ranges of the Rocky Mountains between. At Great Falls was unlimited water power and cheap fuel; at Butte was not enough water for concentration, and expensive fuel. Before the works at Great Falls were started a freight contract was entered into, the rates of which are popularly supposed to be not much over $1.00 per ton of ore for this 175 miles of haul over an elevation of 6,000 feet. By way of contrast, I examined a mine in Nevada, only 100 miles from fuel and water by rail, but $3.50 per ton was the lowest freight named for a seven per cent. copper ore.

Recently competition between railroads and falling prices for metals have introduced into the question of transportation a new

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factor, that of the application to ores of the "milling in transit" applied to wheat. You know that a railroad will take a contract to carry wheat from Dakota to New York at a certain price, consenting that the wheat shall be stopped at Minneapolis, turned into flour, packed in barrels, and the flour go forward under the original contract. There are likewise shipments of ores in which the freight contract is based upon the number of pounds of copper and lead which they contain, as determined by assay, the contract covering the transportation of the ore from the mine to the smelter in the Middle West and the bullion from the smelter to the Eastern market; all considered under one contract, not completed until the bullion is delivered. You can readily see the necessity for carefully considering the question of transportation before deciding where to locate works, from this brief outline.

There is still another question of transportation which has been often overlooked by producers of precious metals by smelting, whose product is in the form of rich lead or copper bullion; and when I have suggested that it was worthy of consideration I have been met sometimes with incredulity until the interested parties began to figure: that is the difference between freight and express rates on precious metals from the Rocky Mountains to, say, New York.

Take for illustration the Anaconda Copper Mining Company. The freight on its product in the form of converter bars or anodes probably does not exceed $15.00 per ton to the Atlantic seaboard, and, of course, the gold and silver contained in the copper pay the same freight by the ton. During the fiscal year ending June 30, 1896, the Anaconda Company shipped about 108,000,000 pounds of copper, containing about 6,000,000 ounces of silver and 16,000 ounces of gold. The freight on these 206 tons of gold and silver, at, say $15.00 a ton, amounted to not much over $3,000.00; but had this material been refined entirely in the West, and the fine gold and silver all been sent forward by express, the expressage and insurance at 2 cents per ounce would have amounted to $120,000.00, difference enough to erect an electrolytic refinery in the East from the saving of two years. In the East, labor is cheaper, sulphuric acid cheap, and there is a market for the incidental sulphate of copper produced. Then again, the distance from market of the finished product has great influence with the location of works, especially for ultimate refining, as freights are higher as a rule on finished products.

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As a result of these conditions, slowly realized, sentiment at present is strongly in favor of the erection of copper refining works on the Atlantic coast, or at least in the East, and it is doubtful whether any of the large copper producers would have put up their electrolytic plants in the West had they realized that the conditions of to-day would prevail, unless it be those fortunate enough to be located on the Great Northern, with the water power of the whole Missouri at Great Falls to draw upon.

Of the fifteen electrolytic refineries in the United States, all are east of Chicago, except three. One-half of the output of the Anaconda is refined in Baltimore, and for the next two or three years all of the United Verde Copper Co.'s output, of Arizona, will also be refined near the port of New York. The entire product of the Canadian Copper Co.'s copper-nickel mines at Sudbury. Ontario, is also refined near New York, and all the copper producers west of the Mississippi treat their material, ultimately, in the East, except three.

Of course, what has been said does not apply to gold milling, nor in so great a degree to lead smelting, although much Western lead is refined in the East.

This brings us to the second division of this talk, and I trust enough has been said to cause you to realize the importance of studying not only topography and fuel supply before deciding where your works shall be, but also the transportation and railway situation.

II.

The second part of this informal talk has to do with questions of sampling and assaying. While some of you will be mining engineers in practice and some metallurgists, perhaps others of you will stand between as public samplers and assayers. Since theory is of little value when compared with practice, and since I am asked by your professors to give you the benefit of my experience, you will doubtless pardon more or less personal allusion in what follows.

While the mining engineer and metallurgist—unless, indeed, the electrical engineer can be called a metallurgist—will find their greatest opportunity in the West, the analytical chemist, assayer and sampler, will find, in all probability, his largest opportunity in the East, or at least as far east as the great manufacturing and re-

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fining centres of Omaha and Chicago. He must remember, in choosing his location, that not alone is he to be called upon to handle material going to buyers' works, or those of refiners on toll, but also material destined for export to Europe, and, moreover, a commercial laboratory should seek all branches of analysis.

In 1880, when my laboratory was opened in New York, there was very little assaying of ores or metals at this port, excepting iron ores. The chief support of an analytical laboratory was from manufacturers of chemicals, fertilizers, etc. In those days chemists received from $5 to $7 for a nitrogen determination, and $4 for determination of phosphoric acid. To-day some are glad to receive one dollar for nitrogen determinations, and from $2 to $2.50 for phosphoric acid. Not only has the price fallen, but the demand for rapid work has become more exacting. One of the first things the chemist discovers on graduation is that he must invent short-cut methods if he would keep his business. I was "brought up" on Fresenius and taught, for instance, that phosphoric acid could only be safely determined after fusion, separation of silica, solution in nitric acid, precipitation as phospho-molybdate; this after twelve hours' standing dissolved in ammonia, precipitated as ammonia-magnesia phosphate—after standing twelve hours filtered, ignited, etc., etc.

This means at least forty-eight hours; but I was startled upon opening my laboratory to have the first man who brought in a sample of phosphate say he must have the results before three o'clock the same day. All business changes. The assayer of the last two decades has seen the testing of chemicals, drugs, etc., almost disappear from his laboratory, if unwilling to accept nominal prices, and sometimes because trade customs have eliminated analysis. For instance, all the bleaching powder and all the alkalis imported used to be sold on American test. Now the European test is accepted on these in spite of the fact that the trade chemists of England still use an admittedly erroneous atomic weight in calculating the analyses of potash compounds. The analyst, moreover, finds keen competition in his business arising from old established firms, nevertheless alive to modern methods, or from other chemists who can, and will perhaps, work more cheaply than he. There are foreigners in this business here, who in some cases live over their laboratories or in them, whose highest ambition is, apparently, an income of $100 per month, and

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who have brought the price of sugar testing, for instance, from $2 per sample down to 25 cents, within my memory. Then there are trade newspapers who, by way of advertisement, have laboratory annexes, and at reduced rates issue certificates of test for dyestuffs, groceries, drugs and chemicals; and then in some centres there is the additional competition of men employed by manufacturing or other institutions, with assured salaries, but with the privilege of doing outside work, who do not depend upon their laboratories alone for a living, and who can cut prices proportionately. There is nothing whatever in this competition that is unprofessional or unfair, but it must be reckoned with, and a specialty should be chosen, if possible.

While the analytical business has suffered, the assaying of ores and metals has increased in the East, and in the eighties there seemed to me to be an opening for an ore sampling plant at this port. Here again the transportation problem had to be considered. It is vitally important for such works to be on a line or at a point where railway pools cannot bottle you up, as it is doubtful if your prestige and reputation would be sufficient to bring business to your works, in the face of switching charges or higher freight rates than those obtained over other roads and at other points.

In locating our sampling works, having ascertained the amount of business likely to be brought to the road upon which we located, we interviewed the general managers of several trunk lines terminating at this city. Their reception was characteristic of the roads. The manager of one line did not exactly quote the language of its "Commodore" when he expressed contempt for the general public, but he evidently had no use for ore samplers. Another line offered a piece of ground on the meadows several miles from water transportation, but would make no guarantee against competitive freights. A third road not only gave the land at a nominal rental, but contributed a considerable proportion of the labor and material necessary to erect the works, entered into a contract that it would protect the sampling works against cut rates offered by other roads; and in addition, agreed that ore or other products coming to this port could be stopped not only for sampling but for storage, and upon the completion of the sampling or storage, the road would take them over again and complete the haul and lighterage under the original bill of lading. This is storage in transit. It may be said that this road construed this

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contract with extraordinary liberality. For instance: When, in 1889, Mr. Sécrétan, of Paris, cornered the world's output of copper, buying the entire visible supply, and the entire product of nearly all the mines, sampling was pretty lively at the works mentioned. As the syndicate approached its disastrous end, copper matte began to halt at the sampling works until nearly 8,000 tons had accumulated. Then the syndicate went to pieces, and its creditors fell foul of one another in dividing up the assets. The copper matte was the subject of protracted litigation. It remained in the sampling works—most of it—seven years, at the end of which time the original bags had rotted and carloads were inextricably mixed. Upon the settlement of the dispute at law the matte was ordered out. The musty bills of lading and lighter notices were produced, and the railroad sent its empty cars, transported and lightered to ocean steamers some 7,000 tons, seven years after it had started from its Western point of production. These sampling works in turn brought to the Erie Railway for several years a business of 50,000 tons annually. Choose your location with care.

We have found as another bit of experience that not simply must one be sure of the road's ability to meet its obligations, if we are obliged to tie ourselves up to one line, but must forecast as far as possible conditions of routing and export. Some two years ago roads running southeast from Kansas discriminated against the port of New York, and not only did they quote a lower freight to Gulf ports, but via Gulf ports to Europe. The result was, much of our sampling had to be done on the docks at Galveston, New Orleans, etc. This has temporarily been put a stop to by the Cuban war, and New York is again securing the bulk of lead and copper freights, even when the material is produced in Arizona.

Of late years there has grown up in this, as in other lines of business, the endeavor to get rid of the middle man—in this case the public sampler and assayer—and buyers and sellers have entered into contracts in which the sampling is to be done at buyer's or seller's works by representatives of both parties. There have been such contracts recently entered into, and questions are already arising which cause one or both of the parties most interested financially to regret them. Buyers and sellers are necessarily suspicious of one another on general principles, especially in deal-

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ing with material of great value, and some are beginning to realize that it is unwise to place themselves under suspicion, however unjust. In one works, owned by the same people who own the mines, such serious differences arose recently between the respective superintendents that it ended in an agreement, not only that they should revert to independent sampling, but that the material should be sampled on neutral ground. It is perhaps justly said that it is too much to expect of average human nature that impartial sampling shall exist at the works or the mine of an interested party. The office sees so much lead, copper, gold and silver charged on the books and holds the works responsible for this amount either in inventory or shipments. The smelter, therefore, must "protect itself against the office," and if mistakes are made they are apt to be on the safe side where sampling is at either seller's or buyer's establishment.

Neither sampling nor assaying is an exact branch of science, especially when dealing with materials containing the precious metals. Your practice in assaying has shown you what variation you can get in any samples, as you vary fluxes, temperature and time of fusion or cupellation. Let me strongly advise you to make every effort, whether you are a seller, buyer or sampler of ore or furnace products, to have the sales contract specify how the assays shall be made. Let me illustrate: Suppose you are to handle Russell process or other rich precipitates or any sulphide residues.

Shall you determine the loss in slag, the error due to volatilization and to cupel absorption? This will increase your result quite twenty per cent. in silver, under ordinary conditions. Shall you use the all-scorification or combination method on copper-gold bars or mattes? The difference in gold reported will be considerable.

Now as to sampling methods: In the early eighties our chief export of furnace material was in the form of copper ores. We sampled hundreds of cars of ore from Montana, running 50 to 60 per cent. of copper. The lead ores then, as now, stopped in the West, only the bullion coming to the seaboard for export or refining. Then came a period of enormous exports of copper matte; next began the era of bessemerizing, applied to copper, and converter bars became the chief support of the sampler. These mattes contained less than 30 ounces of silver to the ton on the average, and no silver was paid for unless there were over 30 ozs.

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Then the electrolytic refinery came in, and as silver and gold were more easily extracted, the mines sought out gold and silver-bearing ores and run up the values present. To-day, the exports and treatment of furnace products near New York consist of quite two-thirds converter copper bars, as compared with one-third mattes.

I have no time to enter into details of sampling or assay methods, but refer you, if interested, to the discussion of those to be found chiefly in the Transactions of the American Institute of Mining engineers, and in Vol. I. of "Mineral Industry" for 1892.

I will give you, however, a few practical examples in connection with copper.

In an article prepared by me in 1892 for the latter work, I dismissed the problem of sampling copper bars with little more than by quoting with approval the requirements of the London Metal Exchange's "Contract J:" the bars to be sampled "by boring half way through on opposite sides near opposite ends." But conditions have changed.

The gold values in the new fields of British Columbia have enormously increased the danger and difficulty of buying and selling on any sample. The converter bars of Trail, B. C., or Northport, Wash., now contain from 97 to 99 per cent. of copper, from 15 to 200 ounces of silver, and from 10 to 20 ounces of gold per ton. They all come East, but how can they be sampled? They are generally cast in molds about two feet long, by 10 inches wide, by six inches deep, tapering toward the bottom—the very worst possible shape to sample by drilling. But, worst of all, the precious metals are very unevenly distributed. Keller has shown that the distribution depends on the impurities present. Boltons, Elliotts, Lewis and other English refiners have proved that silver goes with the sulphur, usually toward the top, and all admit that the variation is influenced by the rate of cooling. A single illustration will suffice:

As preliminary to an investigation I am now conducting at the Laurel Hill Chemical Works, the management bored 100 holes on the top and 45 on the bottom of an average converter bar made of Rossland (B. C.) ores, containing about 99% copper. The borings were taken for separate assays every 1½ inches, with the following results:

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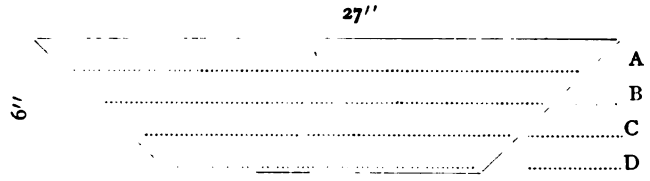
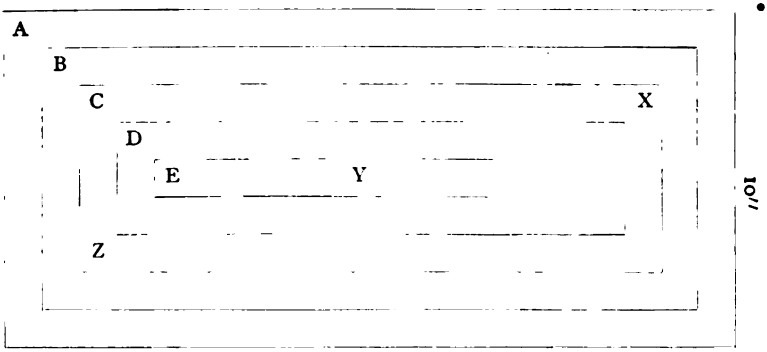
VERTICAL SECTION.



	Silver.	*Gold.*	(ozs. per ton.)
On line A,	137.	17.56	"
" " B,	89.	14.13	"
" " C,	78.	13.56	"
" " D,	64.	12.39	"

Another trial gave the following result:

PLAN OF TOP OF PIG.



		Au.	*Ag.*		*Au.*	*Ag.*
Section A,	1½″ holes,	14.32	100.	3″ holes,	13.45	85.
" B,	" "	13.00	94.		12.25	69.
" C,	" "	17.48	141.		14.93	105.
" D,	" "	21.41	219.		16.85	139.
" E,	" "	18.57	173.		24.52	300.

Gold varies from 12 to 24 ozs. per ton.
Silver " " 69 to 300 " "

My own experience shows almost as much variation in any converter bars, although the values are not usually so high, and the danger is, therefore, less. Only experiment with each class of product can show you a safe rule for each. The surest generally applicable method is to melt down the bars, take dip samples, cast these into thin plates, and drill the latter. But this cannot be done at a public works, and if done at buyer's works you must be present day and night, see to it that the furnace was cleaned out well,

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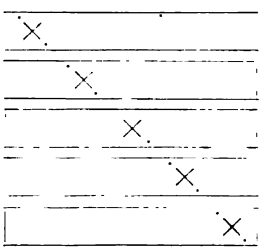
that the bottoms have already been saturated; you must weigh the bars and the anodes or other refined product, weigh and assay the slag, and sample and assay what is left in the furnace, as it is hard to ladle a furnace absolutely dry. The bars in question are sampled by us by boring each thrice, all the way through, at the points marked X, Y, Z, uniting the drillings. These are either ground fine and mixed for assay or, better, melted and cast into a plate, and bored. This is as fair a way as any that can be devised by boring. Bars of less silver and gold contents we bore at points that successively and collectively cover the entire surfaces—top and bottom—thus:

o	o	o	o	o
1	2	3	4	5
o	o	o	o	o
6	7	8	9	10
o	o	o	o	o
11	12	13	14	15

The first bar is bored at 1, the second at 2, the third at 3, etc., and the borings mixed.

Thin plates, like anodes, have an even distribution of values in gold and silver, and no special precautions are needed in drilling for sample. Perhaps the ultimate solution of the problem will be the abandonment of the old Chili Bar mould and of lugs or ears, and the casting of all converter copper into plates, say 24 x 10 x 2 inches in size.

In some English works and in two, at least, in this country, bars are sampled like lead bullion; that is as to the location of the holes. They are laid side by side—three or five in a row. A line is drawn diagonally from end to end, and the sample drawn where this line crosses the centre line of each bar, thus:



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I have stated that it was not my intention to repeat details of assay methods, as you have received these in your ordinary course, and you are fortunate in having in your professors men who have come in actual contact with the commercial and business side of these questions, as well as being thoroughly posted in the theory. Nevertheless, as I see that I have a few minutes left of my hour, I will give you one or two more practical suggestions.

Copper mattes are no longer sampled by taking a tenth, as was customary before they were so rich in the precious metals, as is usually the case to-day; but with the exception of non-Argentiferous mattes—now the scarcest of all in the market—they are sampled by taking one-third or one-fifth as a minimum, usually by putting the whole through the crusher, rolls and automatic samplers; it is extremely difficult and very dangerous to sample such material by hand, and should only be resorted to when it is impossible to do otherwise. The variation in copper mattes as we receive them is not only due to the carelessness of some smelters in making shipments, which will vary very considerably in richness in the same car; such, for instance, as results when bessemer and reverberatory mattes are mixed. But all pigs of matte vary in their different parts, even more erratically than do copper bars, and when gold-bearing cannot be properly sampled by any method of chipping or breaking off pieces, only by crushing the whole.

Perhaps a word on the subject of weighing may interest you, as this is also a part of the duties of the public sampler to-day. Weigh masters should be sworn in. In some States provision is made by law for sworn weighers. The weigh master goes before a notary and swears that he will conduct the business of weighing impartially, and without favor to interested parties. We have adopted this practice at the port of New York, although there is no law on this subject in this State.

Weighing is usually performed on a beam scale. It is the simplest apparatus that can be devised, and is capable of accuracy even in the hands of the most ignorant weigher. The weight is usually not taken when the beam is level, in weighing ores or crude mattes, but when it just begins to rise, which gives in practice an allowance of a few ounces in each draft of say 600 lbs. in favor of the receiver of the material.

This is the trade custom universally adopted by all public weighers, and probably arose from the fact that ores and mattes,

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whether bagged or not, cannot be handled without losing something, if nothing more than the dust which sifts through the covering. This loss in material exported in bags is very considerable. The bags must be unloaded from the cars on the dock, transferred to a lighter, transferred from the lighter to the ocean steamer, and upon arriving transferred from the steamer to a lighter and again to the wharf. It is almost impossible to prevent freight handlers from using hooks, which tear the bags and entail a loss in addition to that certain to arise from legitimate handling.

I have warned all foreign buyers that they must expect a loss of at least 1% in weight on material shipped in bags, as between the port of New York and any port of Europe. Platform scales are frequently used in weighing where the material is handled at buyer's works. A platform scale is a more delicate instrument than a beam scale and weighs closer, but is much more liable to get out of order, and it is much more difficult to detect an error due to imperfection in the scale than when the ordinary beam is used. No possible error can exist in the beam scale, except that due to the enlargement of the notches by long use, or difference in the weights employed, through constant abrasion. It should be the rule to test the scales by standard weights once every day.

As matte increased in value buyers have begun insisting that it shall be shipped in casks rather than in bags, in many cases being willing to pay the extra cost for such packing.

Of course, questions of moisture are carefully looked after at the time of sampling and weighing, large samples of many pounds being taken and dried in steam-jacketed ovens to determine the loss in water.

Speaking of weights leads me naturally to warn you that in dealings with Great Britain, where tons of ore or furnace material are mentioned, to be very sure what kind of a ton is meant. In this country we know the standard or short ton of 2,000 lbs., or 20 cwt. of 100 lbs. each, and we have the long ton—so-called—of 2,240 lbs. You know also that a "hundredweight" is not 100 lbs., in Great Britain but 112 lbs.; but, perhaps, you do not know that ores and mattes are sold there by a different ton still, known as the "miner's ton," which consists of 21 cwt. of 112 lbs. each, or 2,352 lbs., so that in buying a ton of ore you would receive 2,352 lbs.

A word also may be said about the Cornish assay for copper. It is unlikely that the coming generation of ore dealers, standing

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between this country and Great Britain, will meet this relic of ancient tradition. But during the last twenty years the Cornish assay for copper has been very much in evidence in our ore trade with Great Britain. You know that all our contracts in America, as well as those entered into in Germany and France, for copper material, are based upon the percentage of copper which the material contains, as determined by assay, and the assayer is usually left to select his own method, only held closely by both parties to the understanding that his results shall show *how much* copper the material contains. Of course, the electrolytic assay is that most frequently employed, and is, by all odds, the most accurate. But for a century the Cornish method prevailed in Great Britain, and is an attempt to imitate in the laboratory, the furnace operations. A sample of a sulphide ore, for instance, is roasted, fused into a first matte, re-roasted, fused into a second matte, then brought into the form of blister copper, then refined, and the final button of copper is weighed and reported as the "produce" of that particular lot of material. It may differ anywhere from ¼% to 3% from the actual amount of copper that the material contains, but fairly shows the English refiner how much copper he can expect to save out of the material in question, and he bases his prices accordingly. The American buyer, on the other hand, has before him only the total amount of copper which the sample contains and must protect himself in the price he offers against the difficulties in smelting the material bought; if it contains lead, arsenic, antimony, or such impurities, he will naturally give less per pound of fine copper, as shown by assay, than in buying material free from these deleterious substances. Now as to invoices: I show you two account sales, based on English and American methods, respectively, which speak for themselves. The first is an actual transaction in England, in 1886:

Account Sales of 2077 Bags Copper Matte.

Ex. "Baltic," @ New York. Sold on Account of .....

1886.

April 27, Produce, 66¼ per cent. Cu. @ 8s.6d. pr. Unit. Payt. = 2 Mos.

		T.	cwt.	qrs.	lbs.		
Contract.	Weighing,	31.	0.	0.	0. N.		
	cwt. qrs. lbs.						
Mar. 22, Moisture, 30 Gns :	2 2 18						
Draft, 3½ lbs. pr. 3 cwt.:	6 1 23		9	0	13		
2240 lbs.=20 cwt.		30	10	3	15		
2352 " =21 "		29	1	3	17	£28. 3. 1½.	818 17 7
Weighing,		19	6	2	0 N.		

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	cwt. qrs. lbs.				
Moisture, 3% Gns:	1 3 26				
Draft,	4 0 2	.. 6 0 0			
		19 0 2 0			
		18 2 2 .. @		28 3 1½.	510 3 3
Weighing,		25 5 0 0 N.			
	cwt. qrs. lbs.				
Moisture, 35 Gns.:	2 2 3				
Draft,	5 1 1	.. 7 3 4			
		24 17 0 24			
		23 14 .. .. @		28 3 1½.	666 7 4
Weighing,		21 10 0 0 N.			
	cwt. qrs. lbs.				
Moisture, 31 Gns.:	1 3 17				
Draft,	4 1 26	.. 6 1 15			
		21 3 2 13			
		20 3 2 .. @		28 3 1¼.	567 16 4

	cwt. qrs. lbs.		lbs.		
Empty Bags. Good 240 wg.:	1 3 25 @	5s. pr.	120	.. 9 2	
" Bad 1837 "	14 3 20 @	2s. 6d. "	"	1 14 10	2 4 ..
					2565 8 6

Charges.

Insurance on £2600 @ 5s. per cent.	£6 10 ..		
Less Discount @ 10 per cent.	.. 13 ..	5 17 ..	
Plus Stamps,		.. 6 6	6 3 6
April 19. { T. cwt. qrs. lbs. Freight on 97 12 3 17 G. @ 5s. pr. ton		24 8 3	
{ Primage @ 5 per cent.		1 4 5	25 12 8
T cwt qrs lbs. Pd.:—Master port'ge on 97 12 3 17 G. @ 1s. pr. ton, 70 per cent.		£5 7 5	
Less 15 per cent. for not weighing,		.. 16 2	
		4 11 3	
Plus 2¼d. pr. ton for putting into Flats,		.. 18 4	5 9 7
Dock and Town dues on 96¾ Tons @ 1s. 4d. pr. ton,			6 8 11
Lighterage from steamer to ore wharf,			5 .. ..
Assaying each lot for copper,			1 10 ..
Interest on frt. chgs., from 19 Ap. to 30 June, 72 dys.:			.. 8 8
Liverpool Ore Wharf charges for: Receiving, weighing, warehousing, stowing in shed, crushing, sieving, mixing, sampling, reweighing, delivering, rent, etc.:			
97¼ tons @ 6s. per ton,			29 6 6
Commission on £2565 8 6 @ 1 per cent.			25 13 .. 105 12 10
Net proceeds due in cash, 30th June, 1886,			£2459 15 8

E. & O. E.,
Liverpool, 29th May, 1886.

AMERICAN SYSTEM.

Messrs. .....

Sold for Account of

Messrs. .....

93 Bbls Copper Matte, assaying, ... 47.55% copper.
Silver, per ton of 2000 pounds, . . . 117.50 ounces.
Gold, " " " . . . 0.12 "
Moisture, ... 0.01%

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Weight, ...	116,853 pounds.		
Less Moisture, . .	12 "		
Net Weight, . .	116,841 "		
Copper assay, less 1.3 units, ...	46.25%		
Copper paid for, 46.25% of 116,841 pounds, ...		54,039	pounds.
Silver paid for, being 95% of all present, ...		6,864.41	ounces.
Gold paid for		7.01	"
54,039 pounds Copper, at 7¼ cents,	$4,188.02		
6,521.19 ounces Silver, at 67¼ "	4,385.50		
7.01 " Gold, paid for at $20,	146.20	$8,713.72	

This transaction is dated November 21, 1895.

I call your attention to the curious deductions and allowances in the English account.

First, a "draft" of 3½ lbs. is subtracted from every 3 cwt. in weighing. There is a charge, for primage, for master porterage, for dock dues, for town dues, etc., etc.

Since silver began to fluctuate in value and have so uncertain a future, it has been quite customary to base contracts on the price obtainable on the date of future delivery of furnace material; sometimes the New York quotation, sometimes the London quotation is taken as a basis.

But my time is up, and if these thoughts, out of many which have suggested themselves, will convince you that there is a field for very careful study which lies between the mine and the furnace, or the furnace and the market, they will serve a useful purpose.

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AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

By ALFRED J. MOSES, PH.D.

CHAPTER XI.

DETERMINATION OF THE OPTICAL CHARACTERS OF BIAXIAL CRYSTALS.

Some of the determinations are exactly as described under the uniaxial. References may therefore be made of follows: *Faster and slower ray*, p. 146; *Retardation*, p. 146; *Strength of double refraction*, p. 147; *Thickness of section*, p. 147.

Determination of Planes of Vibration or "Extinction."

In biaxial crystals complete extinction in general is only obtained with monochromatic light, p. 276. The methods of determination are as described, p. 145.

In sections normal to one of a, b, or c the extinction directions are the other two principal vibration directions. In sections parallel to a, b, or c one extinction direction must be a principal vibration direction. In sections normal to an optic axis no extinction directions are obtained. The general relation between extinction directions and optic axes is described, p. 275. This test is often sufficient to determine the crystalline system, especially when an entire crystal can be examined and the extinction directions determined in all faces and zones.

In orthorhombic crystals extinction will always be *parallel or symmetrical* to crystallographic edges, cleavage cracks, etc. In pinacoidal faces the vibration direction will be parallel to the crystal axes.

In monoclinic crystals there will be parallel or symmetrical extinction in the zone [001 100] and in this zone the vibration directions in the base and orthopinacoid will be parallel to the axes. In all other zones the extinction will be *oblique*.

In triclinic crystals all extinctions will be oblique.

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THE ORIENTATION AND DISTINCTION OF THE PRINCIPAL VIBRATION DIRECTIONS.

If the positions of the optic axes are known then all three principal vibration directions a, b and c are also known, for a and c are the bisectrices of the angles between the optic axes and b is normal to their plane. The indices α, β and γ may then be determined, as described later, and the indicatrix and ray surface therewith constructed.

In orthorhombic crystals the pinacoids are normal to a, b and c. That normal to b will show with convergent monochromatic light hyperbolæ* similar to Fig. 243 and those normal to a and c will show lemniscates, Fig. 270.

In monoclinic crystals the clinopinacoid is necessarily either normal to b and shows the hyperbolæ, Fig. 243, with convergent monochromatic light, or is normal to a or c and shows lemniscates. The extinction directions therein are the other two principal vibration directions, and the faster and slower ray may be distinguished as described, p. 146. Plates may be ground normal to these directions.

In triclinic crystals by trial a face is found which with convergent monochromatic light shows, even eccentric, the hyperbolæ or lemniscates or axial image; from this the direction is judged in which a new face may be ground exactly† normal to a principal vibration direction. The extinction directions in the new face will be the other principal vibration directions and the faster and slower rays corresponding may be distinguished as on p. 146. Sections may be ground normal to them. If there is dispersion of bisectrices accurate work will require special sections for each color, if the dispersion is not large, sections for a middle color, usually soda yellow, are used.

DIRECT MEASUREMENT OF THE PRINCIPAL INDICES OF REFRACTION.

(*a*) Prisms with a refracting edge *B*, Fig. 212, parallel to a principal vibration direction will give for minimum deviation, p. 116, a direction of transmission *RS* so lying in an optical principal

* By means of one of the attachments to the polarizing microscope described p. 380–381 sections approximately normal to a, b or c may be tipped so that the lemniscates or hyperbolæ are obtained.

†It is important to leave faces of known forms so that later the ground faces may be goniometrically oriented.

‡The ray which penetrates a nicol when the short diagonal is parallel to *B*.

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section that the ray vibrating parallel‡ to the edge B will yield a principal index. In general the other obtainable index is not a principal index.

By Fig. 259 it is seen that if B is parallel to c the transmission is in ab and the ray vibrating parallel to B yields γ. Similarly if B is parallel to b, β results; and if B is parallel to a, α results.

If the bisector BD, Fig. 212, is also the trace of an optical principal section then the direction of transmission RS for minimum deviation is also a principal vibration direction and both rays yield principal indices.

(*b*) Prisms in which BD, Fig. 212, the bisector of the refracting angle B is a principal vibration direction also give for minimum deviation a direction of transmission RS lying in an optical principal section. Therefore the index of the ray vibrating parallel to BD, that is at right angles to the edge B, is a principal index.

By Fig. 259 it is seen that if BD is parallel to c, the transmission RS being normal to BD lies in the plane normal to c, that is in the optical principal section ba and the ray vibrating parallel to BD or at right angles to B will yield γ. Similarly if BD is parallel to b the ray vibrating at right angles to B will yield β and if BD is parallel to a the ray vibrating at right angles to B will yield α.

If a, b, or c, bisect the exterior angle B, Fig. 212, then is the bisector BD normal to this principal vibration direction and RS parallel thereto, that is for minimum deviation the direction of transmission is a principal vibration direction and both rays yield principal indices. The formulæ under (*b*), p. 131, hold for (*a*) and (*b*).

(*c*) If one face AB, Fig. 228, of a prism is an optical principal section and the refracting edge A is a principal vibration direction, rays normally incident at AB will be transmitted in the direction RS parallel to another principal vibration direction and each ray will yield a principal index. If AB is ab and A is either a or b, Fig. 259, then RS is c and α and β result. The formulæ under (*c*), p. 131, hold good.

(*d*) In any crystal face or section parallel to a principal vibration direction, by the methods and formulæ of pp. 118–123, if this direction is made the direction of transmission the two limit lines, as in p. 132, correspond to principal indices; for instance if the transmission direction is a the two limit-lines correspond to β and γ. If the plate is turned 90° in its own plane the direction of transmission

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will be normal to a principal vibration direction (to a in case given) and the limit-line of the ray the vibration direction of which is at right angles to this direction of transmission will correspond to the third index.

If the plate is parallel to a principal section* then either principal vibration direction used as a direction of transmission will give two of the principal indices.

DETERMINATION OF THE ANGLE BETWEEN THE OPTIC AXES.

This is usually accomplished in a plane parallel plate cut normal to the acute bisectrix. In orthorhombic crystals the same plate will be normal for all colors, but in the other systems this is not so, but if the plate be cut normal for a middle color, say yellow, the results for all colors will be approximately† accurate. The apparent angle,‡ denoted by $2E$, is larger than the true angle, denoted by $2V$, and, since light transmitted in the direction of the optic axis has the middle index β, p. 274, then

$$\beta = \frac{\sin E}{\sin V} \text{ or } \sin V = \frac{\sin E}{\beta}.$$

If $2E$ exceed 180° the plate is usually surrounded by oil or some other dense medium in a vessel with plane parallel sides. Denoting the angle then obtained by $2H$ and the index of the surrounding medium by n

$$\sin V = \frac{n \sin H}{\beta}.$$

By measuring a second plate normal to the obtuse bisectrix there results

$$\sin V' = \frac{n \sin E'}{\beta}$$

* If the plate be parallel to the optic axes the two boundaries approach as the plate is turned and meet at the optic axis. In fact the shape of both sections of the Fresnel surface may be plotted and even the optic axial angle measured. Liebisch, *Grundriss der Phys. Kryst.*, 373.

† The rays can only emerge at the true angle when the optic axes are normal to the surface, as in a sphere or in a cylinder the axis of which is perpendicular to the axial plane; or when the outer medium has the same index of refraction as the ray transmitted in the direction of the optic axis. The former is rarely practicable, the latter will be described later.

‡ Plates normal to obtuse bisectrix yield $V' = 90° - V$.

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but as $2V + 2V' = 180°$ then $V + V' = 90°$ and $\sin V' = \cos V$ whence

$$\frac{\sin V}{\cos V} = \frac{n \sin E\beta}{n \sin E'\beta} \qquad \text{or} \qquad \tan V = \frac{\sin E}{\sin E'}$$

This measurement involves actual rotation of the plate about $\mathfrak{b}$ as an axis between the lenses of a polariscope, the plane of rotation being at 45° to the vibration planes of the crossed nicols and the arms of the hyperbola being brought in succession into tangency with one cross hair. The line joining the optic axes in the images must coincide with the other cross hair.

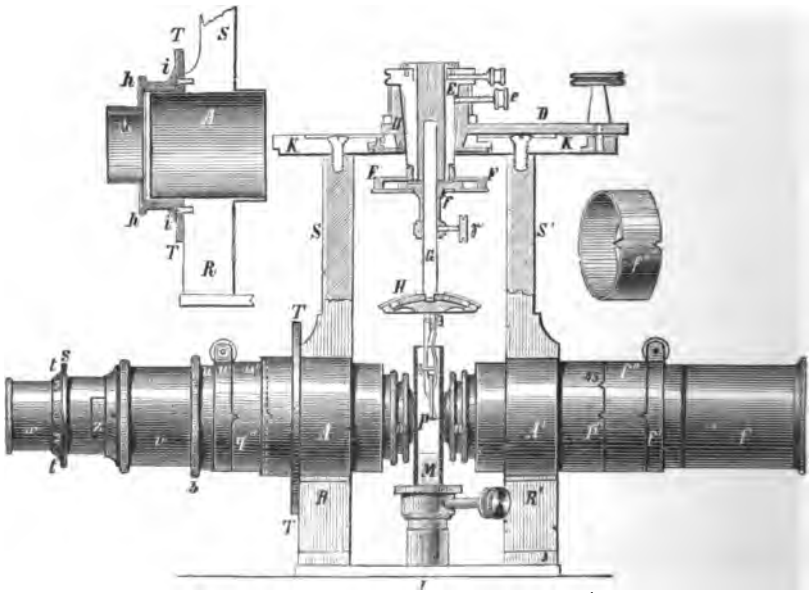

FIG. 273.

The Groth Universal Apparatus. The optical portion of the polariscope shown, Fig. 235, is placed in horizontal position in another stand, Fig. 273. The nicols are crossed at 45° to the horizon and just enough space left between the objectives to permit free rotation of the crystal around a vertical axis. Above is a horizontal graduated circle K with concentric central rings E and F which in turn support the vertical crystal carrier. The latter has motions of adjustment for the crystal plate which in the latest type of instrument are exactly those of the Fuess Goniometer, p. 18, but more frequently are simple sliding motions of a plate at

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f and spherical segment (" mushroom joint ") at *H*. In this simpler type the mineral is centered by drawing the front tube back until the crystal is in focus, then centering as in the goniometer, then the images are centered by the mushroom joint till both stay on a horizontal line.

The closer the lenses the larger the image: that is, a small crystal should be used, and as the best results are obtained with rather narrow interference rings the crystals should be of such a thickness (selected or obtained by grinding) that the lemniscates are distinct. In measuring in a denser medium* the glass vessel *M* is used and the lenses touch its walls.

It is usually a sufficiently accurate selection of a plane normal to a bisectrix if the center of the lemniscate coincide with the center of the field. Groth gives† methods for more accurate determination of the plane.

The No. 2 Fuess Goniometer, Fig. 193, may be used for the measurement of axial angles by substituting nicols for the signal tube in the collimator and for the eye piece in one of the telescopes; both nicols are adjustable. A tube containing a condensing lens is fitted over the objective end of the collimator like a cap and the telescope is converted into a weak microscope by the extra lens used to bring a crystal into focus. The crystal section is carefully mounted as previously described. The telescope is set opposite the collimator, the nicols being crossed 45° to the plane of rotation of the goniometer and rotation of the carefully centered crystals brings the two branches of the hyperbola successively into contact with the vertical cross hair.

By a combination of the axial angle apparatus with a spectroscope‡ the angle for all portions of spectra can be determined.

A Polarizing Microscope may be used, the interference figure being seen:

(*a*) By placing an extra lens§ (Klein's lens) above the eye piece, thus making visible a little image which forms there, or

(*b*) By placing below the eye piece but above the focal plane of the objective a weak magnifying lens (Bertrand lens).

---

*May use olive oil, *a* Brom-Napthalin, Methylene Iodide, etc., see p. 123.

†*Physikalische Kryst.*, 714.

‡A. E. Tutton, *Philos. Trans. R. Soc. London*, 1894, 185, 913. E. A. Wülfing, *Min. Mitth.*, 1896, 15, 49.

§Tschermak's *Min. Mittheil.*, XIV., 375.

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Two methods of measuring are possible:

(*a*) *Measurement of Distances Apart of Emerging Axes.* The nicols are set at the diagonal positions and the distance d from the centre to either hyperbola, or the average of the two distances, is read by either a glass or screw micrometer eye piece. Then $\sin E = \frac{d}{C}$, or in liquid, $\sin H = \frac{d}{NC}$, or $\sin V = \frac{d}{\beta C}$, in which C is a constant for the same system of lenses and is determined once for all with a crystal of known axial angle.

If the section is oblique to the bisectrix it may be tipped so that the axis of the microscope coincides with the direction of a bisectrix, and in this way a well defined interference figure is frequently obtained. A simple instrument for this purpose* consists of a clip supported 15 mm. above the stage by a ball and socket joint giving free motion in all directions, through an angle of about 45°. Delicacy of manipulation is secured by a long key fitting into the clip arm. A special lens combination is needed in order to bring the condenser nearer the section.

(*b*) *Measurement by Rotation of the Section as in the Universal Apparatus.* This involves some form of rotation apparatus attached to the stage of the microscope, by which the angle of rotation can be read. Two forms of one of the simpler devices are shown in Fig. 274. The crystal is fastened by wax to the end of a glass axle the rotation of which is measured on a graduated vertical circle. The crystal projects into a little glass trough filled with refracting liquid and must, by trial, be adjusted so that the plane of the optic axes is vertical. The measured angle is then 2 H. A similar apparatus is described by Bertrand.†

If the rotation necessary to bring the hyperbolæ into tangency with the cross hair cannot be secured on account of the closeness of the objective to the section; one hyperbola may be just brought into the field, then the other hyperbola to the corresponding point on the opposite side of the field. The angle of rotation necessary to install the second point, plus the angle equivalent to 2 d, the distance apart of the two points, will be 2 H.

A much more elaborate device is needed to both orient the axial plane and measure the axial angle. Perhaps the best for the

*Described by T. A. Jaggar, Jr., *Amer. Jour. Sci.*, III., 129, 1897, and made by Bausch & Lomb Optical Co., Rochester, N. Y.

†*Bull. Soc. Min. de France*, III., 96, 1890.

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examination of small complete crystals is the so-called Universal Rotation Apparatus* of Professor Klein, Fig. 275, which is especially designed as an attachment to a No. VI. Fuess Microscope, p. 136. The microscope is tipped with its axis in horizontal position and the plate G of the rotation apparatus fastened to the microscope stage by strong clips so that the axle P is vertical. The crystal is attached at F by wax and centered by the cross hairs of the microscope and the rectangular and rotary movements of the microscope stage. Thereafter it may, while still in the line of sight, be rotated measured amounts in three planes at right angles to each other by the vertical arcs L and L_1, and the horizontal circle K. A small cubical vessel with two opposite walls of glass is filled with a strongly refracting liquid and raised into position between the converger and objective, and so that the crystal is immersed. If by previous examinations p. 375 or from the geometric properties any optical principal section is known, this will be placed parallel to one of the planes of rotation. If by manipulating the arcs L and L_1 with the nicols horizontal and vertical, a position of the crystal is found, such that the field remains dark throughout a complete rotation by K; there is a principal section horizontal, for in no other sections would the vibrations of the refracted rays remain horizontal and vertical, p. 275. If this principal section is the plane of the optic axes, four times in the course of the rotation there will be a brightening of the field due to the emergence of an optic

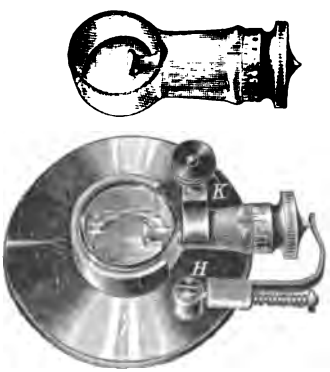

FIG. 274.

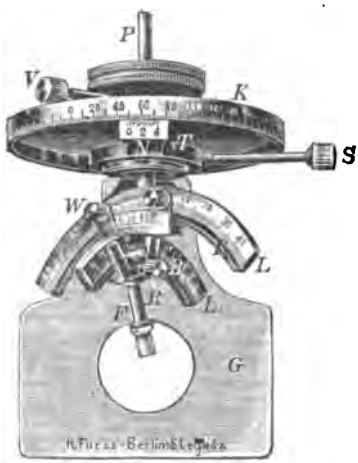

FIG. 275.

* C. Klein, *Sitzungsber. der. Akad. Wissenschaften. Berlin*, 1895, p. 91. "Der Universaldrehapparat," etc.

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axis (internal conical refraction), p. 274. If this does not occur the crystal is remounted with this principal section vertical and parallel to one of arcs L, L_1. Then, if the arc is tipped and trial is made by K, another principal section must be found and 90° away the third, and one of these must be the axial plane.

Having found the plane of the optic axes the approximate positions of the axes are noted, the converger is then introduced, the nicols are set in the diagonal positions, the Bertrand lens inserted or the Klein ocular, the branches of the hyperbola are brought into tangency and the four positions of the emerging axes are read.

A special lens system is needed with this apparatus to counteract the unusual distance between crystal and objective.

Measurement of the True Axial Angle.

If the refracting liquid used in any of the preceding methods has an index of refraction equal β then sin H = sin V. To practically obtain this, a liquid with n a little above β is used and the diluent added drop by drop until the boundaries of the crystals fade. Then for the accurate determination some coarse powder of the substance is placed on an object glass, a drop of the liquid added, a cover glass pressed on and the extinction directions determined in a selected grain. With the condenser lowered and the analyzer out, the two directions of extinction are successively made to coincide with the vibration direction of the polarizer, and the microscope is focussed sharply on the dark boundary between the liquid and the grain. The objective is then raised and the dark boundary line appears to move towards the substance with the higher index of refraction. If the liquid is of the mean refractive index of the crystal the border will for one position move towards the liquid and for the other towards the grain.

A final proof of the correctness of the preparation is that if $n = \beta$ $2H_a + 2H_0 = 180°$, but if on measurement $2H_a + 2H_0 > 180°$, then $\frac{n}{\beta} < 1$ and too much diluent has been added or if $2H_a + 2H_0 < 180°$ then $\frac{n}{\beta} > 1$ and more diluent should be added.

Calculation of Axial Angle from Indices,

This angle may be calculated from the principal indices of refraction by the equation

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$$\tan V = \sqrt{\frac{\frac{1}{\alpha^2} + \frac{1}{\beta^2}}{\frac{1}{\beta^2} + \frac{1}{\gamma^2}}}$$

DETERMINATION OF CHARACTER OF RAY SURFACE.

This requires in general a section normal to a or c that is showing the lemniscates, Fig. 266, with convergent monochromatic light or an oblique section tipped to show these lemniscates.

The difference between the lemniscates formed normal to the acute bisectrix and the obtuse bisectrix cannot always be judged and may require measurement of the axial angle.

If the section is normal to the acute bisectrix then the latter may be proved to be c or a, that is, the Ray Surface proved to be positive or negative as follows:

(*a*) The line joining the optic axes is placed in diagonal position between crossed nicols with parallel white light the insertion of a test plate will determine as described, p. 146, whether this direction is the vibration direction a of the faster ray or c of the slower ray (the other extinction direction being b), that is, whether this section is normal to c or a and p.274, $Bx_a = c, +$; $Bx_a = a, -$

(*b*) With convergent light and crossed nicols the line joining the axial points is placed in diagonal position and the quartz wedge, p. 146, gradually inserted with the direction c parallel to this line. If the crystal is positive the rings around each axis will expand, moving toward the centre and merging in one curve, and will contract and increase in number, if the crystal be negative, the change increasing with the thickness of wedge interposed. If the direction c of wedge and the line joining the axial points are crossed the effects are reversed;* that is expansion of the rings when the length of the wedge is parallel to the line joining the axes proves positive character and expansion when these directions are crossed proves negative character.

(*c*) If with the line joining the axial points in *normal* position the mica plate is inserted in the diagonal position the black cross is destroyed and the rings broken and new flecks developed in the same quadrants as in uniaxial, but the position of the flecks does not so satisfactorily suggest the signs + and —

* Hence it is always practical to develop the lemniscate, even when only the hyperbolæ are visible, by inserting the wedge so as to produce contraction.

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If the section is normal to the obtuse bisectrix all the results are reversed.

CRYSTALS IN THIN ROCK SECTIONS.

The proper orientation of a haphazard section may be obtained with the Jaggar apparatus, but for precise measurement a more elaborate apparatus is essential. The different types of universal stage of von Federow* require the sections to be mounted upon a special round glass with high index of refraction, while the apparatus of Klein, Fig. 276, permits the use of ordinary square or rectangular object glass, the cover glass, however, being removed. The metal plate G is clamped to the microscope stage. The metal vessel B, which is somewhat more than a half sphere, is filled with some liquid of high refractive index usually glyerine $n = 1.46$.

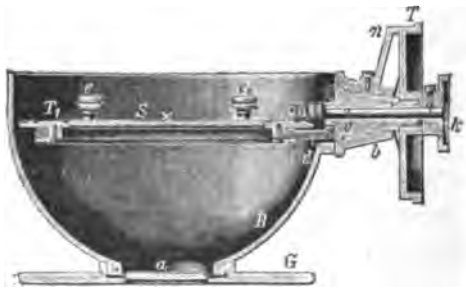

FIG. 276.

The light enters through the glass plate a. The section is supported in the liquid by the glass plate S in the rim T_1 and receives motions of rotation around the horizontal axis c by the graduated circle T, and in its own plane by the knob k, which turns the fine-toothed wheel z in contact with teeth in the rim T_1.

ABSORPTION AND PLEOCHROISM.

The vibration directions of the rays of monochromatic light which undergo greatest and least absorption and a direction at right angles to these constitute the so-called absorption axes. Their lengths are quite independent of the lengths of the axes of the optical indicatrix, but their directions are frequently though not necessarily the same. Upon these axes can be constructed an absorption ellipsoid from which the absorption in all directions can be deduced.

* *Zeit. f. Kryst.* v. 25, p. 351.

† *Sitzungsber. Berlin Akad.*, 1895.

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In orthorhombic crystals the directions of the absorption axes coincide *for all colors* with the directions of crystal axes and the axes of the optical indicatrix.

In monoclinic crystals one absorption axis is parallel to the crystal axis *b*, therefore to one of the axes of the optical indicatrix; the other axes lie in the plane 010, but for any color may or may not coincide with the axes of the optical indicatrix for that color.

In triclinic crystals no coincidence is essential.

Although subject to many exceptions, the law of Babinet is generally correct that "the slower transmitted ray is the more absorbed."

The relative absorption of the two rays for any direction of transmission can be obtained by use of the spectrophotometer of P. Glans, which consists, Fig. 277, of a collimator *C*, telescope *H*

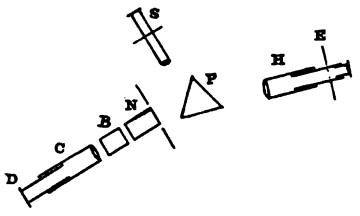

FIG. 277.

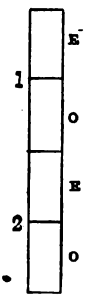

FIG. 278.

and prism *P*. The vertical slit *D* in the collimator is divided into halves by a cross piece of metal, and the entering light passes through a so-called Rochon's quartz prism *R*, which gives a double image, Fig. 278, of each half of the slit, the height of the slit being so chosen that the extraordinary image of one and the ordinary of the other are in contact in the centre of the field and the other two are shut out in the telescope. If now the crystal plate is placed in front of the slit with its extinction directions parallel and at right angles to the slit the two rays developed will pass through the prism *P* and their spectra be seen in the telescope one above the other, and by means of the horizontally movable eye plate *E* any portion may be viewed alone and compared.

By introducing a nicol *N* arranged with a graduated circle, so that when at zero its plane of vibration coincides the principal section of the Rochon prism, either ray may be shut out at will by turn-

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ing the nicol to 0 or 90 and the spectrum of the transmitted ray compared with a spectrum scale sent through S and reflected into the telescope.

A quantitative comparison can be made as follows for any portion of the spectrum. The crystal plate is removed and the angle of rotation α of the nicol determined at which the two spectra of the flame are equally bright; this will be somewhere near 45° but not exactly. The plate is then replaced and the nicol again turned through an angle β to secure equal intensity for the desired portion of the spectrum. The relative intensities are:

$$\frac{I_0}{I_u} = \tan^2 \alpha \cot^2 \beta.*$$

If only one of the halves of the slit is covered the intensity may be compared with that of the incident light.

Transmission along one of the principal vibration directions a, b or c will yield the intensities for vibrations parallel to the other two. As pointed out these are directions of absorption axes in the orthorhombic crystals but not necessarily in the monoclinic or triclinic crystals.

Generally speaking, the records made are simply comparative, for instance: Absorption strong $a > b > c$, or, Absorption feeble parallel a. More commonly the record is as to pleochroism or effect with white light, the color differences for vibrations parallel a, b and c for some middle color being recorded, or, the colors for directions referred to some definite crystal face.†

The pleochroic images are viewed either with a microscope or dichroscope as described, p. 269, or the apparatus of Klein, Fig. 275, may be conveniently used, after the measurement of the angle between the optic axes, by adjusting the crystal with the plane of the optic axes horizontal. If the plane of vibration of the polarizer is vertical and the analyzer is out, the color obtained throughout

*Liebisch *Grundriss der Phys. Kryst*, p. 312.

†Andalusite. Pleochroism a blood red to rose red, b = c olive green. *Dana's System*, p. 496.

Titanite. a = yellowish red, b = greenish red, c = pale yellow. Ripidolite. Yellow to reddish for vibrations normal to 001, green parallel 001. *Rosenbusch Hülfstabellen*, III e.

Axinite. Pleochroism strong, normal to r pale olive-green, giving with dichroscope olive-green and violet blue, parallel r and normal to edge r/M cinnamon brown, giving cinnamon brown and violet blue. *Dana's System*, p. 528.

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a rotation by K corresponds to $\mathfrak{b}$. If the vibration plane of the the polarizer is horizontal, transmission parallel to the bisector of axial angle yields the color for one of $\mathfrak{a}$ or $\mathfrak{c}$ and by a rotation of 90° with K the color of the other results.

ABSORPTION TUFTS.

Plates of crystals with strong absorption, especially if cut normal to an optic axis, often show in convergent non-polarized light two dark tufts symmetrical to the plane of the optic axes, but separated by a bright space. If white light is used the pencils are of different color to the rest of the field.

In Fig. 279, A is the optic axes to which the plate is normal; A' is the other optic axis. Oblique rays emerging at any point m on the line AA' have been transmitted in the plane of the optic axes and, therefore, one of the rays vibrates in the plane of the optic axis, the other parallel to the principal vibration direction $\mathfrak{b}$ or AN. Oblique rays from any point m' on the line AN normal to AA' will vibrate (see p. 275) parallel and at right angles to the bisector of the angle $Am'A'$. As explained by Mallard† the intensity of the pencil of rays emerging at m' is necessarily less than that of the pencil of rays emerging at m, the difference increasing the nearer the points are to each other, that is, normal to AA' is a dark tuft growing lighter on each side of A. Similar effects are obtained for points not on AN, the total result being two tufts or pencils of hyperbolic shape tangent to AA'.

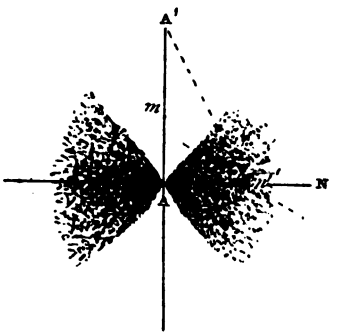

FIG. 279.

When white light is used if the optic axes are dispersed, the tufts are not exactly superposed and the borders show color tints.

The test may be made by holding the crystal section close to the eye and looking at the bright sky or by removing the polarizers from a converging polariscope.

If the plates are examined in convergent polarized light, the analyzer being removed, two types may be distinguished as follows:

* W. Voigt zur Theorie der Absorption des Lichtes in Krystallen *Wiedemann's Ann.*, 1885, XXIII., 577.

† *Traité de Cristallographie*, II., 361.

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TYPE I. The dark tufts will appear normal to the plane of the optic axis and in a clear field, when the plane of the optic axis is normal to the vibration plane of the polarizer. Example: *Andalusite of Brazil.* Plate cut normal to acute bisectrix and placed on a thin plate of azurite shows black tufts on a blue ground.

TYPE II. The same phenomenon results when these planes are parallel. Example: *Epidote of Knappenwand Tyrol.* Cleavage plate parallel 001 gives tufts symmetrical to 010, with white light the borders towards the acute bisectrix are dark green and the opposite are dark red.

In both types, with a rotation of the plate through 90° from these positions, tufts also appear parallel to the plane of the optic axes.

METALLIC REFLECTIONS OR METALLIC LUSTRE.

The metals do not obey the usual laws of reflection; incident plane polarized light is reflected as such, only when the plane of vibration of the incident light is parallel or at right angles to the plane of reflection; and in both of these cases there is developed a change of phase, which is, however, greater in the latter case than in the former. For all other azimuths of vibration the vibration of the reflected light is the result of two unequal* components at right angles and is, therefore, elliptically polarized.

The intensity† of the reflected light differs also from that obtained with transparent substances. For normal incidence it is not zero, but considerable, decreasing as the angle of incidence increases up to a value of 50° to 60°, thereafter again increasing until the angle of grazing incidence is reached.

For a given incidence certain colors are reflected by metals more strongly than others, whereas, transparent substances, even if colored, reflect white light. The combined effect of this intense and selective reflection is called *Metallic Lustre.*

*Varying from 0 for normal incidence to $\lambda/2$ for grazing incidence and for a particular angle, which is experimentally found to be the angle of maximum polarization of common light, passing through the value $\lambda/4$.

† Cauchy, Voigt and Drude have studied the phenomena and calculated the indices of refraction and absorption for a number of metallic substances for different vibration directions upon fresh cleavage surfaces. For gold and silver a higher velocity of light was found than in air, but very high absorption; for lead, platinum and iron the indices of refraction were high, but the absorption relatively low. Very high absorption indices were obtained for stibnite and galena. Kundt discovered phenomena of double refraction of light transmitted through extremely thin electrically deposited metallic films.

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SURFACE COLORS.

Between metallic and transparent substances are certain which are transparent for light of certain wave-lengths, but stop others so completely that even with thin sections they are represented in the spectrum* by absorption bands. These rejected colors are reflected.

When white light is used the reflected or *surface* color is strikingly unlike the transmitted or *body* color, for instance, a drop of fuchsin solution dried on a glass plate shows the surface color green with metallic lustre and the body color red, or if a glass be laid over the surface color is blue-green. A crystal of potassium permanganate polished to a thin layer on glass gives a yellow surface color and a dark violet body color.

The surface and body colors are only approximately complementary as Wiedemann† has shown. The surface colors in uniaxial crystals, moreover, are non-polarized when reflected from basal sections, but dichroic, that is, elliptically polarized and made up of two components vibrating in and at right angles to the plane of reflection for other sections. For instance, with crystals of magnesium platinocyanide the light reflected from the basal plane is violet and not to be decomposed, whereas the green color from a prism face is always resolvable into two colors varying with the angle of incidence.

FLUORESCENCE.

Certain organic compounds, fluorite containing dissolved organic matter and uranium glass possess the property of absorbing light and again emitting it as light of a different color. If sunlight is focussed on a dilute solution of quinine sulphate it becomes deep blue near the surface of entrance. If the spectrum of the transmitted light is examined the violet and ultra violet rays are missing, that is these have in the solution been turned into blue. A test tube of the solution held in a solar spectrum beyond the visible rays becomes blue.

In fluorite and uranium glass, which are isotropic, the color produced is independent of the direction of transmission. In the

*Christiansen found that the spectrum of the red solution of fuchsin lacked green and that blue was deviated more than red.

†*Ann. de Phys.* v. 151, p. 625, 1874.

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uniaxial magnesium platinocyanide crystals* with sunlight passed through blue or violet glass the green surface color disappears on the prism faces, and by polarizing either the incident or emerging light a dichroic fluorescence is observed, scarlet red for vibrations normal to the optic axis, orange yellow for vibrations parallel to the optic axis. If the violet rays are incident normal to the base, polarization reveals only one color, orange yellow, whatever the azimuth of the vibrations.

PHOSPHORESCENCE.

Phosphorescence, or the emission of light by a substance in the dark after it has been exposed to light, heat, friction, mechanical force, or an electrical discharge, has not been clearly shown to be dependent in any way upon the crystalline structure. It is developed by one process or another in a large number of minerals and salts.†

THE NORREMBERG AND REUSCH COMBINATIONS OF MICA PLATES.

The optical phenomena of combinations of differently oriented layers of a doubly-refracting substance are of great value in the development of theories of structure. Muscovite in which the acute bisectrix is nearly normal to the cleavage plane is especially convenient for these experiments.

If two plates of muscovite of equal thickness are laid so that their axial planes are at right angles, then with parallel light and crossed nicols, the phase difference originated in one is exactly compensated by that in the other, and the field will be dark throughout rotation of the stage. With convergent light four axes will emerge equally distant from the centre and between them thin hyperbolic color curves, the asymptotes to which form a black cross.

Norremberg discovered* that if the plates were made so thin that the phase difference of the rays developed in any plate was less than a wave-length, and that if a pile of 12 to 36 of these were made the axial planes in adjacent plates being at right angles, then not only did the compensation of the phase differences give a dark field with parallel light and crossed nicols, but with convergent light the isochromatic curves produced by the oblique rays were

*Lommel in *Ann. de Phys.*, VIII., 634, XLIV., 311.

†D. Hahn, Phosphorescenz der Mineralien, *Zeit. f. d. ges. Naturwiss.*, Bd. XLIII., 1, 131, 1874.

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circles, that is, the effect of the pile was exactly equivalent to a basal section of an uniaxial crystal, Fig. 280.

Reusch found, * by piling 12 to 36 similar plates so that the axial planes of adjacent plates were at 120° to each other as in Fig. 281, that with parallel incident light there emerged a plane polarized ray, the vibration plane of which had been rotated in the direction of the piling through an angle proportionate to the thick-

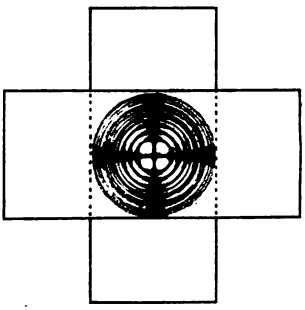

FIG. 280.

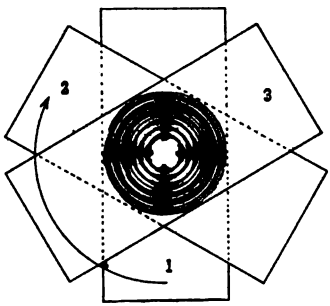

FIG. 281.

ness of the pile that is, if starting at the lowest plate the piling had been with a change in the direction of the hands of watch the rotation was also in that direction, and the color produced with white light would, by rotation of the analyzer, also in the direction of the hands of a watch, pass in the order, red, orange, yellow, green, blue, violet.

With convergent light Fig. 281 resulted, the centre being colored.

This conforms strictly to the behavior of a basal plate of right-handed quartz, except that by rotation of the stage, a slight change of color takes place, this, however, decreases as the mica plates are made thinner.

If the piling were in opposite direction the rotation of the plane of vibration would be opposite and the color order also. Based on these and similar experiments, theories as to the structure of certain crystals have been developed by Mallard,† Sohncke and others.

* *Berichte. Ak. Wissens. Berlin*, July 8, 1869, p. 530.

† *Traite de Cristallographie* II., 262–304; *Zeit. f. Kryst.*, etc., XIX., 529.

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THE BALLISTIC GALVANOMETER AND SOME OF ITS APPLICATIONS.

By W. H. FREEDMAN, E.E.

A ballistic galvanometer is an instrument designed for the purpose of measuring the whole quantity of electricity which passes in a current of short duration. It is so called because the moment of inertia of the moving system is made so great, and consequently the period of vibration so long, that the current has begun and ended before the moving system has sensibly moved from its initial position; just as in a ballistic pendulum the change of momentum of an impinging bullet has entirely taken place before the pendulum has moved from the position of stable equilibrium which it has under the action of gravity. A ballistic galvanometer may be a modified Thomson in which the moving system is a set of weighted magnetic needles, or a modification of the D'Arsonval type. To the latter class belong movable coil voltmeters, as for example the well-known Weston instrument. The same theory, by merely assigning to the symbols the proper significance, fits all of these instruments.

For simplicity let us confine our attention to the case of a galvanometer in which the movable system is a magnetic one. Arrange matters so that in the zero position the needle lies parallel to the plane of the coils and also parallel to the lines of force of the field. Now imagine the needle to be moving due to a current flowing in the coils, but not yet having reached its furthest displacement. Call the kinetic energy of the moving system W. For any particle of mass m moving in a straight line with velocity v we have

$$W = \tfrac{1}{2} m v^2.$$

If the particle rotate around an axis distant r, with angular velocity ω,

$$v = r\omega.$$

But

$$\omega = \frac{d\theta}{dt},$$

therefore

$$v = r\frac{d\theta}{dt}$$

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and $$W = \tfrac{1}{2} mr^2 \left(\frac{d\theta}{dt}\right)^2.$$

Or for any mass

$$W = \tfrac{1}{2} \Sigma mr^2 \left(\frac{d\theta}{dt}\right)^2$$

But $\frac{d\theta}{dt}$ will be constant and Σmr^2 is in mechanics the moment of inertia, I, therefore,

$$W = \tfrac{1}{2} I \left(\frac{d\theta}{dt}\right)^2. \qquad (1)$$

From the principle of conservation of energy any decrease in this kinetic energy must appear as work done. The rate at which the kinetic energy varies is $\frac{dW}{dt}$ and the total change in the time dt must evidently be $\frac{dW}{dt} dt$. During the time dt as the angular velocity must be finite, the angle swept over can only be $d\theta$. Again the work done in rotation equals the moment of the force overcome, multiplied by the angular displacement. The force overcome in this instance, if for the time being we neglect all the other resistances, is only the magnetic one whose moment is $MH \sin \theta$, M being the magnetic moment of the needle and H the strength of the field. We, however, have also a force due to the current, x, in the coils assisting the motion. The moment of this force is $MGx \cos \theta$, where G is the galvanometer constant. Accordingly

$$-\frac{dW}{dt} dt = MH \sin \theta d\theta - MGx \cos \theta d\theta.$$

Substituting equation (1) we get

$$-\tfrac{1}{2} I \frac{d}{dt} \left(\frac{d\theta}{dt}\right)^2 dt = MH \sin \theta d\theta - MGx \cos \theta d\theta.$$

Performing the indicated operation and dividing by $-d\theta$

$$I \frac{d^2\theta}{dt^2} = MGx \cos \theta - MH \sin \theta. \qquad (2)$$

This equation is true for any value of θ. Now let us assume that the needle has not yet started to move and integrate equation (2)

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between the times, $t = 0$ and $t = t_1$, where t_1 is the instant the needle begins to move.

$$I\int_0^{t_1}\frac{d^2\theta}{dt^2}dt = MG\int_0^{t_1}\cos\theta x dt - MH\int_0^{t_1}\sin\theta dt.$$

But θ is constant at zero throughout all this time, so that $\sin\theta = 0$ and $\cos\theta = 1$

$$I\left\{\left(\frac{d\theta}{dt}\right)_{t=t_1} - \left(\frac{d\theta}{dt}\right)_{t=0}\right\} = MG\int_0^{t_1} x dt$$

Now $\int_0^{t_1} x dt$ equals the integral current or total quantity of electricity passed through the coils. The velocity of the needle when t is zero, is evidently zero, and when t is t_1, it is the initial velocity or the velocity with which the needle begins to move.

Calling this $\left(\frac{d\theta}{dt}\right)_0$

we have $$I\left(\frac{d\theta}{dt}\right)_0 = MGQ$$

or $$Q = \frac{I\left(\frac{d\theta}{dt}\right)_0}{MG}. \qquad (3)$$

From equation (3) we see that the initial velocity of the moving system is directly proportional to the total quantity of electricity passed through the galvanometer. Therefore this initial velocity is a measure of Q. Instead of attempting to measure the initial velocity directly however, we express it in terms of more readily determinable quantities. If the moving system of needles has only magnetic forces to overcome, the work done can be determined as follows: The magnetic moment being $MH\sin\theta$, the work done in passing over an arc $d\theta$ is evidently $MH\sin\theta d\theta$ or the entire work W_1 done against the magnetic forces by the needle moving from zero to its elongation θ_0 must be

$$W_1 = \int_0^{\theta_0} MH\sin\theta d\theta.$$

If the entire discharge has passed before the needle starts, the amount of work done must be done at the expense of the kinetic energy of the needle just at starting, or

$$\tfrac{1}{2}I\left(\frac{d\theta}{dt}\right)_0^2 = \int_0^{\theta_0} MH\sin\theta d\theta \qquad (4)$$

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Performing the integration indicated, equation (4) can be placed in the form

$$\left(\frac{d\theta}{dt}\right)_0^2 = \frac{2MH}{I}(1 - \cos\theta_0) \qquad (5).$$

Remembering however that

$$1 - \cos\theta_0 = 2\sin^2\tfrac{1}{2}\theta_0$$

equation (5) becomes

$$\left(\frac{d\theta}{dt}\right)_0^2 = 4\frac{MH}{I}\sin^2\tfrac{1}{2}\theta_0$$

and extracting the square root

$$\left(\frac{d\theta}{dt}\right)_0 = 2\sqrt{\frac{MH}{I}} \cdot \sin\tfrac{1}{2}\theta_0. \qquad (6)$$

This shows that the initial velocity can be expressed in terms o half the angle of the first swing of the needle.

Substituting equation (6) in equation (3) we obtain

$$Q = \frac{I}{MG}\sqrt{\frac{MH}{I}} \cdot 2\sin\tfrac{1}{2}\theta_0.$$

This can be rewritten as

$$Q = \frac{H}{G}\sqrt{\frac{I}{MH}} \cdot 2\sin\tfrac{1}{2}\theta_0. \qquad (7)$$

The next step in the deduction is to substitute in equation (7) the value of $\sqrt{\frac{I}{MH}}$. In order to do this let us confine our attention to the needle after the discharge has taken place and it is swinging back and forth, taking into account only the magnetic forces.

Equation (2) then, since x or the current has become zero, can be written.

$$I\frac{d^2\theta}{dt^2} + MH\sin\theta = 0$$

or since θ will be very small

$$I\frac{d^2\theta}{dt^2} + MH\theta = 0. \qquad (8)$$

This is the equation of motion of the needle since it gives a relation between θ and t, true at any moment. Multiplying by $2d\theta$ equation (8) can be put

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$$\frac{2d\theta d^2\theta}{dt^2} = -\frac{MH}{I} 2\theta d\theta$$

Integrating this between the limits θ_1 and θ_2

$$\int_{\theta_1}^{\theta_2} \frac{2d\theta d^2\theta}{dt^2} = \frac{MH}{I} \int_{\theta_1}^{\theta_2} - 2\theta d\theta$$

or $$\left(\frac{d\theta}{dt}\right)_{\theta_2}^2 - \left(\frac{d\theta}{dt}\right)_{\theta_1}^2 = \frac{MH}{I}\left(\theta_1^2 - \theta_2^2\right).$$

Now let θ_1 be θ_0 the maximum value of θ, and θ_2 any other value whatever. Then since at elongation the velocity must be zero, $\left(\frac{d\theta}{dt}\right)_{\theta_0}^2$ becomes zero and we have the general equation

$$\left(\frac{d\theta}{dt}\right)^2 = \frac{MH}{I}(\theta_0^2 - \theta^2)$$

Extracting the square root and separating the variables

$$\frac{d\theta}{\sqrt{\theta_0^2 - \theta^2}} = \sqrt{\frac{MH}{I}} \cdot dt$$

Dividing both numerator and denominator of the first member by θ_0 and integrating

$$\int \frac{d\left(\frac{\theta}{\theta_0}\right)}{\sqrt{1 - \frac{\theta^2}{\theta_0^2}}} = \sqrt{\frac{MH}{I}} \int dt + C$$

The first member of this equation is of the form $\int \frac{dx}{\sqrt{1-x^2}}$ which equals $\sin^{-1} x$.

Therefore $$\sin^{-1}\frac{\theta}{\theta_0} = \sqrt{\frac{MH}{I}} \cdot t + C$$

Now when t is zero then θ is zero, and since $\sin^{-1} 0$ equals zero then C must be zero.

Consequently $$\frac{\theta}{\theta_0} = \sin \sqrt{\frac{MH}{I}} t^2$$

or $$\theta = \theta_0 \sin \sqrt{\frac{MH}{I}} t^2 \qquad (9)$$

This is the equation of a regular sine curve, and shows that the motion is a simple harmonic. It also shows, as is evident should

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be the case since we have neglected all frictional resistances, that the vibration continues indefinitely with a constant amplitude. We also see that θ is equal to zero when $t_0 = 0$, and again zero when

$$\sqrt{\frac{MH}{I}} t_1^2 = 2\pi$$

the needle having made one complete oscillation, or when the time

$$t_1 = 2\pi \sqrt{\frac{I}{MH}}$$

Now calling the time of vibration of the magnet T_0, that is, the time taken for θ to pass from a given value to that value again when it is increasing in the same direction, we have

$$T_0 = t_1 - t_0 = 2\pi \sqrt{\frac{I}{MH}} \qquad (10)$$

Substituting the value of $\sqrt{\frac{I}{MH}}$ from equation (10) in equation (7) we obtain

$$Q = \frac{H T_0}{\pi G} \sin \tfrac{1}{2}\theta_0 \qquad (11).$$

In deducing equation (11), everything has been neglected except the magnetic forces. There are, however, other forces which in practice are not negligible. There effect is to so change the oscillations of the needle as to make the actual time of vibration longer than T_0 and the first elongation less than θ_0. It therefore becomes necessary to determine the corrections to be applied in order to obtain a working formula. Besides the magnetic moment to be overcome, there are in reality three others which should enter equation (2), and are:

1st. The torsional moment. This is due to the torsion of the suspending fibre and is given by Hooke's law as proportional to θ so that it equals $a\,\theta$.

2d. The frictional moment. The only mechanical friction encountered is air friction. In general this depends on the velocity and on the form of the body, but for small velocities and smooth bodies, such as prevail here, it is proportional to the velocity or equal to $b \frac{d\theta}{dt}$.

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3d. The moment due to eddy currents. The magnets being of conducting material, their motion in a magnetic field induces currents in them which by Lenz's law oppose the motion producing them. The induced E. M. F.'s being proportional to the rate of change of the tubes of induction it is evident that the eddy current moment is proportional to the velocity or equal to

$$c\frac{d\theta}{dt}.$$

Consequently equation (2) should really be

$$I\frac{d^2\theta}{dt^2} = MGx\cos\theta - MH\sin\theta - a\theta - b\frac{d\theta}{dt} - c\frac{d\theta}{dt}. \quad (12)$$

Now $x = 0$ before the needle moves, that is, the discharge has completely taken place; θ can be written for $\sin\theta$ on account of the small deflections; $a = 0$ or in well constructed Thomson instruments torsion can be neglected and $b + c$ can be written A.

Therefore equation (12) in our case becomes

$$I\frac{d^2\theta}{dt^2} + A\frac{d\theta}{dt} + MH\theta = 0. \quad (13)$$

This is the true equation of motion instead of equation (8) and from it we shall be able to obtain the proper values for the time of vibration and the first elongation. It is impossible, however, to integrate equation (13) twice and thus directly find the relation between θ and t. We shall therefore follow the method of finding the solution of differential equations. We know that $\theta = f(t)$ and that this function must contain two arbitrary constants on account of the double integration involved. Now if it is possible to write down such a function of t as will contain two arbitrary constants that when substituted together with its first and second derivatives in equation (13) it will satisfy it, then this will be the relation between θ and t we are seeking, provided the arbritrary constants are given the proper values.

Suppose we assume $\theta = e^{mt}$

accordingly $$\frac{d\theta}{dt} = me^{mt}$$

and $$\frac{d^2\theta}{dt^2} = m^2e^{mt}.$$

Substituting in equation (13)

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$$Im^2e^{mt} + Ame^{mt} + MHe^{mt} = 0$$

or

$$Im^2 + Am + MH = 0. \qquad (14)$$

That is, we have entirely eliminated our variables, and if m is given the value obtained from equation (14), then e^{mt} will satisfy equation (13). Further, it is evident we will find two roots of equation (14), m_1 and m_2, so that $e^{m_1 t}$ and also $e^{m_2 t}$ will each be a solution. Accordingly, $C_1e^{m_1 t}$ and $C_2e^{m_2 t}$ will also each be a solution because either will merely make every term of the first member of equation (13) a constant times its present value, which constant can be divided out since the second member is zero. Then finally $C_1e^{m_1 t}+C_2e^{m_2 t}$ must be a solution. For it is merely the sum of the individuals and each being zero their sum must be again zero; it also contains two arbitrary constants. The solution therefore is

$$\theta = C_1e^{m_1 t} + C_2e^{m_2 t}. \qquad (15)$$

Solving equation (14) by ordinary algebra the values of m are found to be

$$m_1 = -\frac{A}{2I} + \sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}$$

and

$$m_2 = -\frac{A}{2I} - \sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}.$$

Substituting these values in equation (15) we have

$$\theta = C_1e^{\left(-\frac{A}{2I} + \sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}\right)t} + C_2e^{\left(-\frac{A}{2I} - \sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}\right)t}. \qquad (16)$$

We know that when $t=0$ then $\theta=0$ for the needle has not yet started to move. These values substituted in equation (16) give

$$0 = C_1 + C_2$$

or

$$C_2 = -C_1.$$

Therefore $\theta = C_1e^{-\frac{A}{2I}t}\left(e^{\sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}\cdot t} - e^{-\sqrt{\frac{A^2}{4I^2} - \frac{MH}{I}}\cdot t}\right)$. (17)

If we remember that

$$\sin x = e^{\frac{x\sqrt{-1} - e^{-x\sqrt{-1}}}{2\sqrt{-1}}}$$

then

$$2\sqrt{-1}\sin x = e^{x\sqrt{-1}} - e^{-x\sqrt{-1}}$$

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Accordingly arrange equation (17) in the form

$$\theta = C_1 e^{-\frac{A}{2I}t}\left(e^{\sqrt{\left(\frac{MH}{I}-\frac{A^2}{4I^2}\right)t^2}\sqrt{-1}} - e^{-\sqrt{\left(\frac{MH}{I}-\frac{A^2}{4I^2}\right)t^2}\sqrt{-1}}\right)$$

and we at once see that

$$\theta = C_1 e^{-\frac{A}{2I}t} 2\sqrt{-1}\sin\sqrt{\left(\frac{MH}{I}-\frac{A^2}{4I^2}\right)t^2}.$$

Calling $$2C_1\sqrt{-1} \equiv K$$

gives $$\theta = Ke^{-\frac{A}{2I}t}\sin\sqrt{\left(\frac{MH}{I}-\frac{A^2}{4I^2}\right)t^2}. \qquad (18)$$

θ is zero when t_0 is zero and also when

$$t_1 = \frac{2\pi}{\sqrt{\frac{MH}{I}-\frac{A^2}{4I^2}}}$$

for then the value of the sine in equation (18) is zero. Consequently the time of vibration T_1, taking into account air resistance and eddy currents is

$$T_1 = t_1 - t_0 = \frac{2\pi}{\sqrt{\frac{MH}{I}-\frac{A^2}{4I^2}}}. \qquad (19)$$

We also see that neglecting the effect of these makes $A = 0$ and equations (18) and (19) reduce to equations (9) and (10) as they should. We also recognize K as being θ_0, the maximum deflection when no frictional resistances exist.

Substituting from equation (19) in equation (18) we have

$$\theta = \theta_0 e^{-\frac{A}{2I}t}\sin\frac{2\pi}{T_1}t. \qquad (20)$$

At the first, third, fifth, etc., quarter periods we get the maximum deflections or elongations, the successive maxima differing from each other and gradually growing less. Substituting these values for t in equation (20) we have the corresponding values of θ or the successive elongations, so that for

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$$\left.\begin{aligned} t_1 &= \frac{T_1}{4}, \quad \theta_1 = \theta_0 e^{-\frac{A}{2I}\frac{T_1}{4}}, \\ t_2 &= \frac{3T_1}{4}, \quad \theta_2 = \theta_0 e^{-\frac{A}{2I}\frac{3T_1}{4}}, \\ t_3 &= \frac{5T_1}{4}, \quad \theta_3 = \theta_0 e^{-\frac{A}{2I}\frac{5T_1}{4}}, \end{aligned}\right\} \qquad (21)$$

etc. etc.

It is evident that

$$\left.\begin{aligned} \frac{\theta_1}{\theta_2} &= e^{-\frac{A}{2I}\frac{T_1}{4} + \frac{A}{2I}\frac{3T_1}{4}} = e^{\frac{AT_1}{4I}} \\ \frac{\theta_2}{\theta_3} &= e^{\frac{AT_1}{4I}} \\ \frac{\theta_{n-1}}{\theta_n} &= e^{\frac{AT_1}{4I}}. \end{aligned}\right\} \qquad (22)$$

And in general

So that we see the ratio between any two successive elongations is constant or the amplitudes are decreasing in a constant ratio.

Passing to logarithms the last of equations (22) becomes

$$\frac{AT_1}{4I} = \log \frac{\theta_{n-1}}{\theta_n} = \lambda. \qquad (23)$$

This quantity is called the logarithmic decrement. Since, however, the decrease in two successive swings is very small, the ratio $\frac{\theta_{n-1}}{\theta_n}$ is so near unity that λ would always appear to be zero. Consequently λ is determined in the following manner. From equations (22) we observe

$$\frac{\theta_1}{\theta_2} \times \frac{\theta_2}{\theta_3} \times \frac{\theta_3}{\theta_4} \times \cdots \frac{\theta_{n-1}}{\theta_n} = e^{(n-1)\frac{AT_1}{4I}}$$

$$\frac{\theta_1}{\theta_n} = e^{(n-1)\frac{AT_1}{4I}}$$

$$\log \frac{\theta_1}{\theta_n} = (n-1)\frac{AT_1}{4I}.$$

So that

$$\lambda = \frac{AT_1}{4I} = \frac{1}{n-1} \log \frac{\theta_1}{\theta_2}. \qquad (24)$$

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If s_1 is the scale reading corresponding to θ_1, and s_n that corresponding to θ_n, then if L equals the distance of the mirror from the scale in scale divisions since the angles are small

$$\theta_1 = \tan\theta_1 = \frac{s_1}{2L}$$

$$\theta_n = \tan\theta_n = \frac{s_n}{2L}$$

and

$$\frac{\theta_1}{\theta_n} = \frac{s_1}{s_n}. \tag{25}$$

Substituting equation (25) in equation (24)

$$\lambda = \frac{1}{n-1}\log\frac{s_1}{s_n}$$

or

$$\lambda = \frac{1}{n-1}(\log s_1 - \log s_n). \tag{26}$$

Since the Naperian logarithm of any number is equal to 2.3026 times its common or Brigg's logarithm, expressed in the latter

$$\lambda = \frac{2.3026}{n-1}(\log_{10} s_1 - \log_{10} s_n). \tag{27}$$

The logarithmic decrement can thus be easily and accurately determined from either equations (26) or (27) by merely reading any two elongations from the scale and noting n. This quantity has been dwelt upon because knowing it we can at once calculate T_0 and θ_0 from the observed values of T_1 and θ_1.

For squaring equation (19) it becomes

$$T_1^2 = \frac{4\pi^2}{\frac{MH}{I} - \frac{A^2}{4I^2}},$$

or

$$\frac{MH}{I}T_1^2 - \frac{A^2T_1^2}{4I^2} = 4\pi^2.$$

But from equations (10) and (23)

$$\frac{MH}{I} = \frac{4\pi^2}{T_0^2}$$

$$\frac{A^2T_1^2}{4I^2} = 4\lambda^2.$$

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Substituting these values

$$\frac{4\pi^2 T_1^2}{T_0^2} - 4\lambda^2 = 4\pi^2$$

which gives

$$T_0 = \frac{\pi T_1}{\sqrt{\pi^2 + \lambda^2}}. \tag{28}$$

Again, if

$$\lambda = \frac{AT_1}{4I}$$

the first of equations (21) becomes

$$\theta_1 = \theta_0 e^{-\frac{\lambda}{2}}.$$

Expanding by Maclaurin's theorem and neglecting all powers after the first, since λ is very small

$$\theta_1 = \theta_0 \left(1 - \frac{\lambda}{2}\right)$$

or

$$\theta_0 = \theta_1 \left(\frac{1}{1 - \frac{\lambda}{2}}\right).$$

Performing the indicated operation and only keeping the first powers

$$\theta_0 = \theta_1 \left(1 + \frac{\lambda}{2}\right). \tag{29}$$

Substituting the values of T_0 and θ_0 from equations (28) and (29) in equation (11), it becomes

$$Q = \frac{HT_1}{G\sqrt{\pi^2 + \lambda^2}} \sin \tfrac{1}{2}\theta_1 \left(1 + \frac{\lambda}{2}\right).$$

Since θ_1 will be very small

$$\sin \tfrac{1}{2}\theta_1 \left(1 + \frac{\lambda}{2}\right)$$

is the same as

$$\left(1 + \frac{\lambda}{2}\right) \sin \tfrac{1}{2}\theta_1.$$

Also in sensitive galvanometers λ will be so small that λ^2 can be neglected with respect to π^2. Therefore the true working equation

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of the ballisitic galvanometer, taking air resistance and eddy currents into account, becomes

$$Q = \frac{HT_1}{\pi G}\left(1 + \frac{\lambda}{2}\right)\sin\tfrac{1}{2}\theta_1. \qquad (30)$$

The most important physical measurements employing a ballistic galvanometer are the following:

1st. Measurement of coefficients of self and mutual induction.

2d. Determination of the capacity of a condenser.

3d. Measurement of number of lines of force.

4th. Determination of the permeability and the hysteresis loss per cycle of samples of iron or steel.

Measurement of the Coefficients of Induction.

The coefficient of self induction of any coil not having an iron core is easily determined by making it one of the arms of a Wheatstone's Bridge as CD in Fig. 1, the galvanometer being a ballistic one. Balance the bridge for steady currents and then open the key K. When this key is again pressed down so as to complete the circuit, although there will be no current through the galvanometer when the currents get steady, yet, a transient current will flow through the galvanometer, in consequence of the electromotive forces which exist in CD arising from the self induction of the coil. This current though only transient is very intense while it lasts and causes a finite quantity of electricity to pass through the galvanometer producing a finite kick. We can calculate this quantity as follows: an electromotive force E in the arm CD will produce a current through the galvanometer proportional to E; let this current be kE. If L is the coefficient of self-induction and i the current in the arm CD, then the instantaneous E.M.F. produced must be $\frac{d}{dt}(Li)$ and the current that this produces through the galvanometer must be

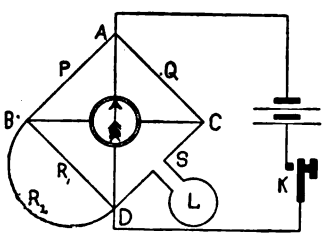

Fig. 1.

$$x = k\frac{d}{dt}(Li).$$

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Integrating this equation from before the key K is closed until after the currents have become steady

$$\int_{t_1}^{t_2} x dt = kL \int_{t_1}^{t_2} \frac{di}{dt} dt.$$

The first member is Q, the integral current, so

$$Q = kL(i_2 - i_1).$$

Now $i_1 = 0$, as the circuit was open and i_2 is the current flowing through CD when the steady state has been reached. Calling this i_0

$$Q = kLi_0.$$

Substituting for Q its value from equation (30)

$$kLi_0 = \frac{HT_1}{\pi G}\left(1 + \frac{\lambda}{2}\right) \sin \tfrac{1}{2}\theta_1.$$

or

$$L = \frac{H}{Gki_0} \cdot \frac{T_1}{\pi}\left(1 + \frac{\lambda}{2}\right) \sin \tfrac{1}{2}\theta_1. \qquad (31)$$

Let us now destroy the balance of the Wheatstone's Bridge by inserting a small additional resistance δS in the arm CD. This will cause a current x' to flow through the galvanometer. To calculate x' the resistance δS must be so small that practically the same current i_0 is flowing through CD as before. The effect of introducing δS then will be the same as if an E.M.F., equal to the increased drop, $i_0 \delta S$ were introduced in CD. This E.M.F. would cause a current to flow through the galvanometer of k times itself

or

$$x' = ki_0 \delta S.$$

But a steady current will produce a permanent deflection φ of the galvanometer, which is acting now as a simple tangent instrument such that

$$x' = \frac{H}{G} \tan \varphi.$$

Therefore

$$ki_0 \delta S = \frac{H}{G} \tan \varphi$$

or

$$\frac{H}{Gki_0} = \frac{\delta S}{\tan \varphi}. \qquad (32)$$

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Substituting equation (32) in equation (31)

$$L = \frac{T_1 \delta S}{\pi}\left(1 + \frac{\lambda}{2}\right)\frac{\sin \frac{1}{2}\theta_1}{\tan \varphi}. \qquad (33)$$

Let us call s_1 the divisions deflections due to the first kick, and s the divisions due the permanent deflection. Now since the angles are small

$$2 \sin \tfrac{1}{2}\theta_1 = 2 \cdot \tfrac{1}{2} \cdot \theta_1 = \theta_1 = \tan \theta_1.$$

But $\tan \theta_1 = \frac{s_1}{2L}$ and $\tan \varphi = \frac{s_2}{2L}$, if L in this case denotes the distance of the mirror from the scale in scale divisions. So that

$$\frac{2 \sin \frac{1}{2}\theta_1}{\tan \varphi} = \frac{\tan \theta_1}{\tan \varphi} = \frac{s_1}{s_2}. \qquad (34)$$

Finally therefore $$L = \frac{T_1 \delta S}{2\pi}\left(1 + \frac{\lambda}{2}\right)\frac{s_1}{s_2}. \qquad (35)$$

The variation of δS is best obtained in practice by a multiple arc arrangement. When P is made equal to Q the disturbance of the balance may be made in the arm BD by using two resistances R_1 and R_2 as shown.

The coefficient of mutual induction of two coils can be determined as follows: Let A and B (Fig. 2) represent the pair of coils of which A is placed in series with a ballistic galvanometer and B in series with a battery and a small resistance S, this second circuit being provided with a key for breaking or closing the circuit. Let R be the resistance of the circuit containing A, while L and M are respectively the coefficients of self- and mutual-induction of this circuit. When the key is depressed the current growing in the circuit containing B sets up a magnetic field which while growing causes a momentary current in A giving a kick in the galvanometer. Let y be the instantaneous value of the current in A, and x the instantaneous value of the current in B. The E. M. F. due to mutual induction will be $\frac{d}{dt}(Mx)$ and that of self induction

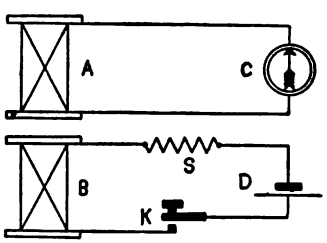

FIG. 2.

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$\frac{d}{dt}(Ly)$ so that we have by Ohm's law

$$y = \frac{\frac{d}{dt}(Mx) - \frac{d}{dt}(Ly).}{R}$$

Integrating this from before the circuit is closed to the time when x has become steady and equal to i

$$\int_0^t y\,dt = \frac{M}{R}\int_0^t \frac{dx}{dt}\,dt - \frac{L}{R}\int_0^t \frac{dy}{dt}\,dt$$

$$Q = \frac{M}{R}(x_2 - x_1) - \frac{L}{R}(y_2 - y_1)$$

But x_1, y_2 and y_1 are all evidently zero while $x_2 = i$, so that

$$Q = \frac{M}{R}i.$$

Substituting for Q its value from equation (30)

$$\frac{M}{R}i = \frac{HT_1}{\pi G}\left(1 + \frac{\lambda}{2}\right)\sin\tfrac{1}{2}\theta_1. \qquad (36)$$

Now cut the circuit containing the coil A and connect its ends to the terminals of S; then if R is very large compared with S this will not alter appreciably the current flowing around B. On this supposition the current flowing round the galvanometer circuit will be by the theory of shunts equal to $\frac{S}{R+S}i$ and if φ is the corresponding angle of deflection of the galvanometer,

$$\frac{S}{R+S}i = \frac{H}{G}\tan\varphi. \qquad (37)$$

Combining equations (36) and (37)

$$M = \frac{RS}{R+S}\cdot\frac{T_1}{\pi}\left(1 + \frac{\lambda}{2}\right)\frac{\sin\frac{1}{2}\theta_1}{\tan\varphi}$$

or on account of equation (34) we have finally

$$M = \frac{RS}{R+S}\cdot\frac{T_1}{2\pi}\left(1 + \frac{\lambda}{2}\right)\frac{s_1}{s_2}. \qquad (38)$$

THE DETERMINATION OF THE CAPACITY OF A CONDENSER.

Arrange the apparatus as shown in Fig. (3). C is the condenser whose capacity is to be determined, G the ballistic galvanometer,

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E the battery and K a discharge key. Place the key so that the battery charges the condenser. Then if the condenser is discharged through the galvanometer by moving the key, the quantity of electricity discharged will produce a kick of the needle which we have seen is given by equation (30). If F is the capacity of the condenser and E the electro-motive force of the battery then Q the charge in the condenser is given by

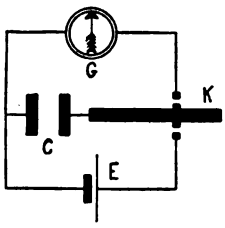

FIG. 3.

$$Q = FE. \tag{39}$$

Therefore combining equations (30) and (39) gives

$$F = \frac{H}{EG} \cdot \frac{T_1}{\pi}\left(1 + \frac{\lambda}{2}\right) \sin \tfrac{1}{2}\theta_1. \tag{40}$$

The condenser must now be disconnected and a resistance box inserted in series with the battery and galvanometer. If the total resistance in circuit be now R then by the theory of the tangent galvanometer

$$i = \frac{E}{R} = \frac{H}{G} \tan \varphi$$

where φ is the permanent angle through which the needle is deflected. Consequently

$$\frac{H}{EG} = \frac{1}{R \tan \varphi}$$

which substituted in equation (40) gives

$$F = \frac{T_1}{\pi R}\left(1 + \frac{\lambda}{2}\right) \frac{\sin \tfrac{1}{2}\theta_1}{\tan \varphi}$$

and on account of equation (34)

$$F = \frac{T_1}{2\pi R}\left(1 + \frac{\lambda}{2}\right) \frac{s_1}{s_2}. \tag{41}$$

By replacing the condenser by a cable submerged in a tank this method applies to determining the static capacity of cables.

MEASUREMENT OF NUMBER OF LINES OF FORCE.

In all magnetic measurements employing a ballistic galvanometer, the instrument is either of the D'Arsonval or voltmeter type or else must be removed to a distance so as not to be dis-

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turbed by the magnetic forces. Consider a coil of wire of S turns in circuit with a ballistic instrument. Place the coil in any magnetic field so that N lines of force pass through the coil. Now imagine the magnetic field to fade away. Then as the lines of force fade away an E.M.F. will be set up in the coil producing a momentary current which will give a kick in the galvanometer. Let x be the instantaneous value of the current, L the coefficient of self-induction and R the resistance of the entire circuit. The instantaneous E.M.F. induced in the coil will be $-S\frac{dN}{dt}$, so that we have

$$x = \frac{-S\frac{dN}{dt} - \frac{d}{dt}(Lx)}{R}.$$

Integrating this equation from the time the field begins to vanish until it is zero, gives

$$-S\int_0 \frac{dN}{dt}dt = R\int_0^t x dt + L\int_0^x \frac{dx}{dt}dt$$

or $$S(N_1 - N_2) = RQ + L(x_2 - x_1).$$

N_2 is zero and N_1 the original number of lines of force; Q is the total quantity of electricity that has passed, while x_2 and x_1 are evidently both zero.

This equation therefore reduces to

$$N = \frac{R}{S}Q. \qquad (42)$$

Substituting from equation (30) the value of Q

$$N = \frac{R}{S}\cdot\frac{HT_1}{\pi G}\left(1 + \frac{\lambda}{2}\right)\sin\tfrac{1}{2}\theta_1. \qquad (43)$$

If now a standard condenser is taken and charged from a standard cell, then its charge becomes known; call this Q_0. If now the condenser be discharged through the same ballistic

$$Q_0 = \frac{H}{G}\frac{T_1}{\pi}\left(1 + \frac{\lambda}{2}\right)\sin\tfrac{1}{2}\theta_1'$$

so that $$N = \frac{R\sin\frac{1}{2}\theta_1}{S\sin\frac{1}{2}\theta_1'}Q_0$$

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which on account of the angles being small will be

$$N = \frac{Rs_1}{Ss_2} Q_0 \qquad (44)$$

where s_1 is the number of divisions deflection due to the lines N and s_2 the number of divisions deflection due to the discharge of the condenser of Q_0 units of electricity.

Calling s_1 merely s and denoting $\frac{RQ_0}{Ss_2}$ by K equation (44) may be written

$$N = Ks \qquad (45)$$

in which K would be the constant of the entire inductive circuit. Therefore we see that the number of lines of force cut are directly proportional to the deflections produced. In measurements where relative values only are desired it is of course unnecessary to determine K as outlined, for a mere comparison of the deflections produced gives the relative number of lines of force.

Owing to the imperfect nature of the magnetic circuit of dynamos and motors, the flux is by no means uniform throughout. Only a portion of the total flux generated in the magnet limbs is available for the establishment of electromotive forces in the armature conductors; the remainder leaks around by various paths, determined to some extent by the design of the machine. The ratio of maximum to useful magnetic flux, or coefficient of leakage, is of much importance in the calculation of magnetic circuits; it is usually denoted by v. In any actual machine this coefficient is best determined by a temporary secondary circuit containing a ballistic instrument. Thus if a few turns of wire be placed around the magnet core, and this wire be made part of a circuit containing a ballistic galvanometer and suitable resistance, then on suddenly making the field circuit of the dynamo or motor, a throw of the ballistic needle will be produced which will be, as we have seen, directly proportional to the magnetic induction within the field core. On breaking the field circuit a throw will be produced in the opposite direction. If now the exploring coil should be wound longitudinally around the armature so as to have the same number of turns as around the field core, and in such a plane as to include the maximum flux, a different deflection will be obtained on making and breaking the field circuit. From a number of observations the

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mean throw for each position can be obtained; the ratio of these is the value of v sought.

Again if an exploring coil of a known number of turns be placed in the rear of the pole piece, for instance, the throw obtained in a ballistic galvanometer in series with the coil when the field circuit is broken will be a measure of the leakage from the surface. This may be conveniently expressed as a percentage of the maximum induction obtained near the middle of the field limb. In this way the entire magnetic circuit can be investigated in regard to leakage. The effect of sharp corners and edges will be fully appreciated as a result of such an experiment.

Determination of the Permeability and the Hysteresis Loss per Cycle of Samples of Iron or Steel.

The work done in passing a unit magnetic pole through a turn of wire carrying a current i is $\frac{4\pi}{10} i$, if i is expressed in amperes. Passing a unit pole through a solenoid having S turns therefore requires an amount of work $\frac{4\pi}{10} Si$. The magnetizing force is numerically equal to the number of lines of force per square centimeter produced provided the medium is air, and is denoted by H. Calling l the length of the solenoid, the work done by moving a unit pole from one end to the other through the turns must be Hl.

Consequently
$$Hl = \frac{4\pi}{10} Si$$

or
$$H = \frac{4\pi Si}{10l} \tag{46}$$

In any simple magnetic circuit of constant cross-section the total flux is given by Hopkinson's formula

$$N = \frac{4\pi}{10} \cdot \frac{Si}{\frac{l}{A\mu}} \tag{47}$$

where N is the total flux, S the number of turns and i the current in the magnetizing coil, l the length and A the cross section of the magnetic circuit and μ the permeability of the material.

Calling the flux density per square centimeter B, we have

$$B = \frac{N}{A} \tag{48}$$

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Equation (47) may be written

$$\frac{N}{A} = \mu \frac{4\pi Si}{10l}$$

Substituting equations (46) and (48)

$$B = \mu H \qquad (49)$$

With the aid of equations (46), (48) and (49) the permeability of any sample may be determined by Hopkinson's divided bar method, of which Fig. 4 shows the connections. The 110 volt

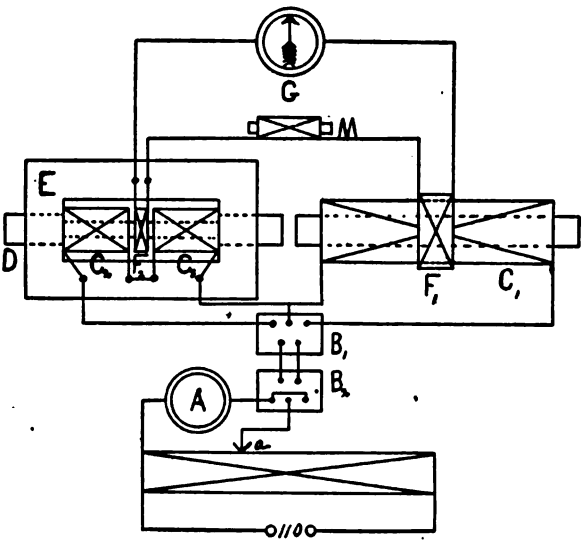

FIG. 4.

circuit is first closed throngh a coil of German silver resistance R. By moving the contact point a any desired current, measured by the ammeter A, can be sent in either direction through the solenoid C_1 or the coils C_2 and C_3 according to the position of the switches B_1 and B_2. D is the sample to be tested, circular in cross-section, in two pieces and smaller where it forms the core of the magnetizing coils than in the large wrought iron yoke E. E is of such dimensions as to act like a magnetic short circuit between the ends of D. Coils F_1, F_2 and F_3 together with the ballistic galvanometer G form the inductive circuit. M is a permanent magnet which is moved so as to induce E. M. F.'s in F in such a direction as to bring the galvanometer to rest.

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The constant K of the inductive circuit in equation (45) is first obtained in the following manner: Send a definite current through C_1 and note the kick produced. The number of lines of force produced can be calculated from equation (46), since the magnetic circuit of the solenoid being air, N is here equal to H. Knowing therefore the kick and the number of lines of force producing the same, K becomes known.

Now send any desired current through C_2 and C_3. Then sepa- D so that F_2, which is attached to a spring, will fly out. In doing so, it will cut all the lines of force induced in the sample and produce another kick in the galvanometer. Thus N becomes known from equation (45). If the number of turns in F_1 and F_2 are not equal, but respectively S_1 and S_2, then their ratio must be introduced and

$$N = \frac{S_1}{S_2} Ks. \qquad (50)$$

B and H can now be calculated from equations (48) and (46) for: measuring the diameter of the sample core by a micrometer, A is its cross-section in square centimeters; i is read from the ammeter; S is the number of total turns in C_2 and C_3, and l is the length of the specimen between the the edges of the yoke in centimeters, all of which are known.

The value of μ corresponding to any value of the current therefore becomes known from equation (49).

TABLE I.

Annealed Wrought Iron.			Grey Cast Iron.		
B	μ	H	B	μ	H
5000	3000	1.66	4000	800	5
9000	2250	4	5000	500	10
10000	2000	5	6000	279	21.5
11000	1692	6.5	7000	133	42
12000	1412	8.5	8000	100	80
13000	1083	12	9000	71	127
14000	823	17	10000	53	188
15000	526	28.5	11000	37	292
16000	320	50			
17000	161	105			
18000	90	200			
19000	54	350			
20000	30	666			

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The corresponding values of B, μ and H of some samples of iron examined by Hopkinson are given in Table I, and the relation between these quantities shown graphically by the curves in Figs. 5 and 6 constructed therefrom.

It is well known that several kinds of magnetic substances exhibit residual magnetism after having been subjected to magnetic forces. Furthermore closed circuits of soft iron will exhibit a considerable amount of residual magnetism, so long as the circuit which they constitute is unbroken. Since the magnetic forces, if sufficiently powerful, produce effects on the molecules of a magnetizable body that remain after the cause has passed away, it follows that if the causes change in a continuous manner the effects

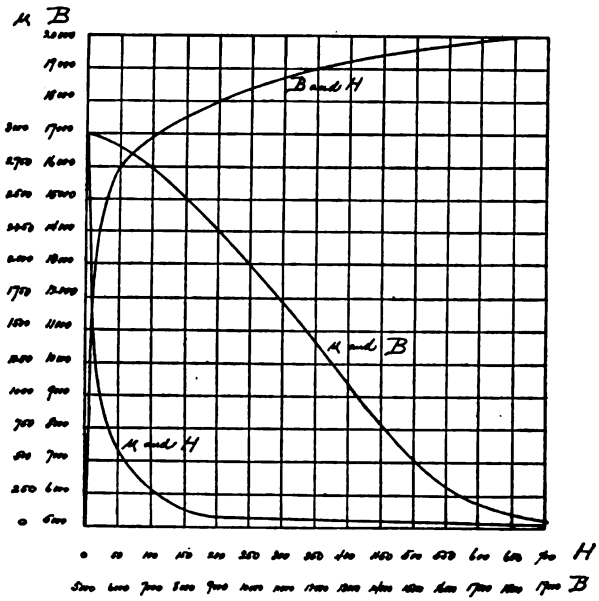

FIG 5. Annealed Wrought Iron.

also change in a continuous manner, but suffer a retardation in phase, the effect lagging after the cause. The curve between B and H shown in Fig. 5 is consequently only true for increasing values of H. If H is gradually increased to a maximum from zero and then gradually decreased to zero, B first increases to a maximum and then decreases but does not curve back to zero. The curve descending from the maximum does not coincide with the ascending curve, but diverges more and more as H approaches zero.

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The number of lines of force per square centimeter that thus remain as the residual value of B is called the *remanence*. To remove this *remanence* a negative magnetizing force must be applied. The particular value of the magnetizing force which is needed to bring the remanent magnetization to zero has been termed by Hopkinson the *coercive force*. Professor Ewing, who has particularly studied

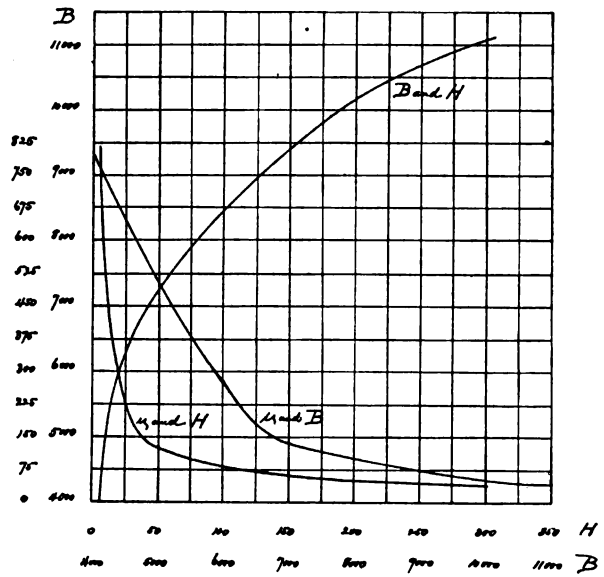

FIG. 6. Grey Cast Iron.

the residual effects exhibited by various qualities of iron or steel, has given the name of *hysteresis* to this tendency of the induction to lag in phase behind the magnetizing force.

Taking now any sample of steel or iron, subject it to a complete cycle. For example, let the magnetizing force begin at zero, rise to a maximum and decrease back to zero; then reverse, rise to a negative maximum and fall again to zero, finally rising to the previous positive maximum. The corresponding instantaneous values of B and H can be determined by the ballistic method as if we were determining the permeability at each point, and when plotted will always give a closed curve similar to Fig. 7. This cycle is taken from Ewing's researches and shows the results he obtained on a sample of annealed steel pianoforte wire.

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The fact that a cycle of magnetization as described always yields a closed curve has been shown by Warburg and Ewing to possess a special significance, for the area enclosed is a measure of the work wasted or converted into heat in carrying the iron through this cycle. Perhaps the simplest way to prove this is to think of the magnetization as being produced by a current in a magnetizing solenoid, and to consider the work done by the current when the magnetism changes. Take as the core of the solenoid a ring or

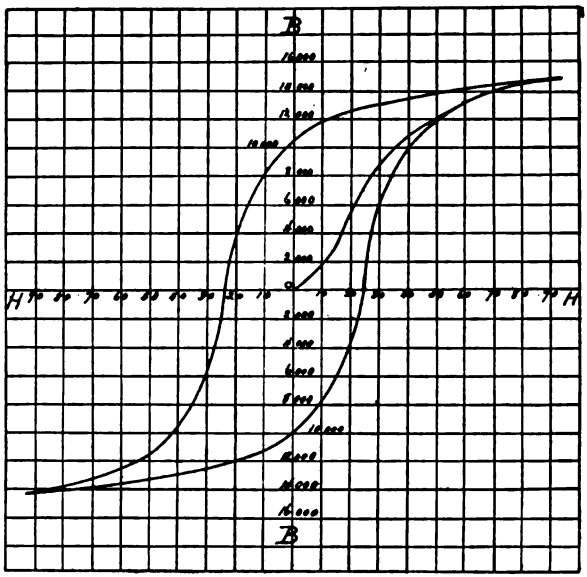

FIG. 7. Annealed Steel Piano-forte Wire.

very long rod of length l and cross-section A, wound with S turns of the wire. Say that its magnetic induction is increased by an indefinitely small amount, dB, in an indefinitely small time, dt, by increasing the magnetizing current to an indefinitely small extent. Then the whole number of lines of induction within the solenoid is increased by the number AdB, and the time-rate of this increase is $A\frac{dB}{dt}$. This induces in the surrounding solenoid an electromotive force equal to $SA\frac{dB}{dt}$ in the direction opposite to that of the current. The current has accordingly to do work in overcoming this opposing electromotive force, over and above whatever further quantity of energy it expends in heating the conducting

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wire. Let i be the mean value the current has during the time dt. The opposing electromotive force, due to the change of magnetic induction in the core, when multiplied by the current and by the time dt, gives the quanty of work done by the currrent in producing the change of magnetism dB and is

$$dW = eidt$$

or

$$dW = SA\frac{dB}{dt}idt$$

or

$$dW = SAidB \qquad (51)$$

The fact that dt disappears shows that this work does not depend on the time-rate at which the change of induction takes place; we have the same quantity of energy used in the process whether the change dB takes place fast or slowly. Since the volume of the core is lA the work done by the magnetizing current per cubic centimeter is from equation (51)

$$\frac{dW}{lA} = \frac{SAi}{lA}dB$$

$$d\left(\frac{W}{lA}\right) = \frac{Si}{l}dB. \qquad (52)$$

If for simplicity we call now the energy per cubic centimeter merely W, equation (52) becomes

$$dW = \frac{Si}{l}dB.$$

But $\frac{Si}{l}$ from equation (46) if i is in absolute units is $\frac{1}{4\pi}H$ and therefore

$$dW = \frac{1}{4\pi}HdB.$$

To obtain the work done per cubic centimeter of the metal when B is changed by any finite amount, caused by changing the magnetizing force from, say, a value H_1 to another value H_2 we have to integrate this expression, finding

$$W = \frac{1}{4\pi}\int_{H_1}^{H_2} HdB. \qquad (53)$$

But $\int_{H_1}^{H_2} HdB$ must be the enclosed area, since H and B are the coordinates of the curve.

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Therefore to determine the hysteresis loss per cubic centimeter for any given cycle proceed as follows: (1) Determine the corresponding values of B and H so as to plot a closed curve similar to Fig. 7. (2) Find the area by a planimeter, or, if greater accuracy is required, by the method of weighing. (3) Then multiply this area by the number of H's per unit length and again by the number of B's per unit length of the scale used in plotting the curve. (4) This product divided by 4π gives the answer in ergs.

If the *hysteresis* loss is determined for one cycle it can be calculated for any other. Steinmetz has shown that the loss of energy due to hysteresis by reversals of magnetism can be expressed with sufficient exactness by the empirical formula

$$H = \eta B^{1.6} \qquad (54)$$

where H = loss of energy per cubic centimeter and per cycle in ergs

B = the maximum value of the reduction per square centimeter

η = a coefficient depending upon the particular sample.

The average values of η for different materials as determined by Steinmetz are given in Table II.

TABLE II.

Material.	η	Material.	η
Very soft iron wire	0.002	Soft annealed cast steel	0.008
Very thin soft sheet iron	0.0024	Soft machine steel	0.0094
Thin good sheet iron	0.003	Cast steel	0.0120
Thick sheet iron	0.0033		
Most ordinary sheet iron } Transformer cores }	0.0040 to 0.0045	Cast iron	0.0162
		Hardened cast steel	0.025

For further information the reader is referred to the following works which have been freely consulted in the preparation of this article: "Electricity and Magnetism," by J. Clerk Maxwell; "Electricity and Magnetism," by Francis E. Nipher; "Elements of Electricity and Magnetism," by J. J. Thomson; "The Electromagnet," by Silvanus P. Thompson; "Manual of Physics and Applied Electricity," by E. L. Nichols; "Elements of Practical Physics," by Stewart and Gee; "Magnetic Induction in Iron and other Metals," by J. A. Ewing; "Transactions A.I.E.E., Vols. IX. and XI.," Steinmetz on Hysteresis.

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THE ASSAY OF TELLURIDE ORES.

By CHARLES H. FULTON.

The growing importance of telluride ores and the fact of their relative difficulty of assay in contrast to other ores, has led to this work. The object of the work is to determine where the difficulty and losses lie, and if possible to remedy these defects of the assay by proper methods and precautions.

Ore No. 1 is a telluride, having a very siliceous gangue. Pyrite is present in small amount.

Ore No. 2 is a very rich telluride from Cripple Creek, Colorado, containing considerable pyrite. The gangue is siliceous.

The ores were finely crushed, No. 1 to 100 mesh and No. 2 to 150 mesh to insure an even sample.

The crucible assay was tried on these ores with various modifications of the charge as regards the amount of litharge present. All assays on ore No. 1 were made with one assay ton of ore. Assays on ore No. 2 were made with 1/5 A. T. of ore. The charges for No. 1 were as follows, except that the litharge increased from one to six assay tons.

1 A. T. Ore.
1 A. T. PbO.
½ A. T. Silica.
1 A. T. Soda.
10 grams borax glass.
2 grams argol.
Salt cover.

The silver in the ore is very small and of no importance; so 20 milligrams of silver foil were added to each crucible assay to give a large button from cupellation and also to avoid subsequent inquartation. Four iron nails were added to each assay to desulphurize and give a malleable button. The weight of the lead buttons ranged from 20 to 48 grams, the increase in weight being due to the increased litharge. All buttons were fairly malleable and were cupelled directly, even the larger buttons, without rescorification. The cupellation was conducted at a low heat with feathers of litharge forming on the cupel. The assays show a regular increase of gold recovered, as the litharge increases in the

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series (see Table I.). A further increase in litharge gave no better result.

The slags from these assays were ground up and mixed with 1 A. T. of litharge, and 2 grams of argol and remelted to determine the loss of gold in the slag. Silver was also added to collect the gold. The cupels were also ground up and mixed with 1 A. T. of PbO, 1½ A. T. of borax glass, 1 A. T. of soda and 2 grams of argol; silver was also added.

The results show that there is a considerable loss of gold in the slag, the average correction being .068 mgs. equivalent to 1.16%. This is much higher than the loss of gold in slag from ordinary ores. The amount of gold recovered from the cupel is small, only .013 mgs. or 0.12%.

It is also to be noted that the corrected assays increase with the greater amount of litharge, as well as the uncorrected assays, which points to the fact that a great part of the loss is due to volatilization.

Table II. shows the effect of increasing litharge on a rich telluride. The charges for this ore were as follows, except for the varying litharge.

1/5 A. T. Ore.
2 A. T. PbO.
1 A. T. Soda.
½ A. T. Silica.
1 gram Argol.

The ore had considerable reducing power and one gram of argol was found to be sufficient to give the right sized button. The crucible slags were remelted and the resulting lead buttons cupelled. The actual loss of gold in slags for this ore is higher than for No. 1, although the percentage loss decreases.

The cupel loss being so small, was neglected in this case.

When the button resulting from the fusion of a telluride ore was brittle, it was usually deemed necessary to rescorify it, before cupellation. A set of assays were run on both ores, No. 1 and No. 2, to determine whether this rescorification was of advantage.

These sets were run in the same way, with increasing litharge as the first two sets, except that no nails were added to ore No. 1, and that all the buttons were rescorified.

The results (see Tables III. and IV.) show that the gold is considerably lower where the buttons are rescorified, and that the loss

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TABLE I.

SHOWING EFFECT OF INCREASING LITHARGE.

No. of Assay.	Amount of Litharge.	Amount of Argol.	Character of Slag.	Character of Lead Button.	Weight of Lead Button.	Amount of Gold.	Gold recovered from Crux-Slag.	Gold recovered from Cupel.	Total amount of Gold recovered.	Percentage recovered from Crux-Slag.	Percentage recovered from Cupel.	Total percentage recovered	Amount of Gold Corrected Assay.
A	1 A. T.	2 gms.	bl'k glassy	Malleable	20 gms.	5.60 mg.	0.03 mg.	0.09 mg.	0.12 mg.	0.52%	1.55%	2.07%	5.72 mg.
B	2 " "	2 "	"	Brittle	37 "	5.52 "	0.16 "	0.02 "	0.18 "	2.76%	.18%	2.94%	5.70 "
B_0	2 " "	2 "	"	"	47 "	5.60 "	0.03 "	0.01 "	0.04 "	0.52%	.09%	.61%	5.64 "
C	4 " "	2 "	gr'n glassy	"	32 "	5.67 "	0.05 "	0.01 "	0.06 "	0.86%	.09%	.95%	5.73 "
C_0	4 " "	2 "	"	"	30 "	5.65 "	0.08 "	0.02 "	0.10 "	1.38%	.18%	1.56%	5.75 "
D	6 " "	2 "	"	Malleable	48 "	5.72 "	0.06 "	0.01 "	0.07 "	1.03%	.09%	1.12%	5.79 "
D_0	6 " "	2 "	"	"	45 "	5.78 "	0.06 "	0.01 "	0.07 "	1.03%	.09%	1.12%	5.85 "
				Averages, . .		5.65 "	0.068 "	0.013 "	0.09 "	1.16%	0.12%	1.48%	5.74 "

TABLE II.

SHOWING EFFECT OF INCREASING LITHARGE. RICH TELLURIDE.

Number of Assay.	Amount of Litharge.	Amount of Ore.	Amount of Argol.	Character of Slag.	Character of Lead Button.	Weight of Lead Button.	Amount of Gold.	Gold recovered from Crux-Slag.	Percentage recovered from Crux-Slag.	Amount of Gold corrected Assay.
1	2 A. T.	½ A. T.	1 gram	green glassy	Malleable	20 grams	89.10 mgs.	0.22 mgs.	1.21%	90.20 mgs.
2	4 " "	½ " "	1 "	" "	"	26 "	90.50 "	0.08 "	0.31%	90.90 "
3	4 " "	⅕ " "	1 "	" "	"	48 "	90.26 "	0.10 "	0.55%	90.36 "
4	6 " "	⅕ " "	1 "	" "	Brittle	28 "	90.30 "	0.09 "	0.49%	90.75 "
						Averages, . . .	90.04 "	0.09 "	0.45%	90 55 "

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TABLE III.

SHOWING EFFECT OF RESCORIFICATION OF LEAD BUTTON.

No. of Assay.	Amount of Litharge.	Weight of Lead Button.	Weight of Button after rescorification.	Amount of Gold.	Gold recovered from Crux-Slag.	Gold recovered from Scorification Slag.	Gold recovered from Cupel.	Total amount of Gold recovered.	Percentage recovered from Crucible Slag.	Percentage recovered from Scorification Slag.	Percentage recovered from Cupel.	Total Percentage recovered.	Amount of Gold Corrected Assay.
E	1 A. T.	17 gms.	8 gms.	5.32 mg.	0.10 mg.	0.16 mg.	trace	0.26 mg.	1.72%	2.76%	trace	4.48%	5.58 mg.
F	2 " "	22 "	14 "	5.62 "	0.06 "	0.04 "	0.01 mg.	0.11 "	1.03%	0.70%	0.18%	1.91%	5.73 "
G	4 " "	30 "	18 "	5.64 "	0.06 "	0.04 "	0.01 "	0.11 "	1.03%	0.70%	0.18%	1.91%	5.75 "
H	6 " "	40 "	14 "	5.50 "	0.08 "	0.03 "	trace	0.11 "	1.38%	0.52%	trace	1.90%	5.61 "
H_0	6 " "	39 "	14 "	5.54 "	0.09 "	0.04 "	trace	0.13 "	1.55%	0.70%	trace	2.20%	5.67 "
I	8 " "	75 "	24 "	5.58 "	0.07 "	—	—	—	1.20%	—	—	—	5.65 "
		Averages, . . .		5.54 "	0.08 "	0.038 "		0.11 "	1.31%	0.65%		1.98%	5.67 "

TABLE IV.

SHOWING EFFECT OF RESCORIFICATION OF LEAD BUTTON. RICH TELLURIDE.

Number of Assay.	Amount of Litharge.	Amount of Ore.	Amount of Argol.	Character of Slag.	Character of Lead Button.	Weight of Lead Button.	Weight after rescorification.	Amount of Gold.	Gold recovered from Crux-Slag.
10	4 A. T.	$\frac{1}{8}$ A. T.	None	green glassy	Malleable	68 grams	29 grams	89.30 grs.	—
11	4 " "	$\frac{1}{8}$ " "	None	" "	"	54 "	26 "	89.60 "	—
12	6 " "	$\frac{1}{8}$ " "	None	" "	"	76 "	24 "	88.50 "	0.20 mgs.
							Average, . . .	89.13 "	

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takes place during rescorification, the greater part of it being due to volatilization.

The crucible slags, cupels and scorification slags were remelted and the buttons cupelled. The loss in the crucible slag is a little higher than in the first set. (See Tables I. and III.)

The average amount of gold recovered from the scorification slag is .038 mgs. equivalent to .65%. The amount recovered from the cupel is very small and less than in set No. 1. (Table I.)

A set of assays was run on ore No. 2 to confirm these results of the disadvantage of rescorification. The results were uniformly lower than when the buttons were cupelled directly; the average result by direct cupellation being 90.04 mgs. and by rescorification 89.13 mgs.

These assays were run with nitre and iron nails, the nitre being added to increase oxidizing action, and the nails to desulphurize and reduce. (Table IV.)

The slags and cupels of this set were not remelted and the assays not corrected.

A charge with cyanide of potassium was also run on ore No. 1 to note the effect.

Ore, 1 A. T.
KCy, 2 A. T.
PbO, 1 A. T.
Salt cover.

The result gave gold 5.40 oz. which is much lower than assays run by the regular charges.

The following are the average results obtained from the four sets of assays.

ORE NO. 1.

Average uncorrected assay when cupelled directly .	5.65 mgs.
Average corrected assay when cupelled directly . .	5.74 mgs.
Average uncorrected assay when button is rescorified	5.54 mgs.
Average corrected assay when button is rescorified .	5.67 mgs.
Average loss of gold in crucible slag	0.075 mgs.
Average loss expressed in per cent	1.23%
Average loss in cupel when cupelled directly . . .	0.013 mgs.
Average loss in cupel expressed in per cent	.12%
Average loss in scorification slag	0.038 mgs.
Average loss in per cent	.65%

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Total gold recovered when cupelled directly	0.09 mgs.
Total gold recovered in per cent	1.48%
Total gold recovered when rescorified	0.11 mgs.
Total gold recovered in per cent	1.98%

ORE NO. 2.

Average uncorrected assay, cupelled directly . . .	90.04 mgs.
Average corrected assay, cupelled directly	90.55 mgs.
Average uncorrected assay when bottom is rescorified	89.13 mgs.
Average corrected assay when button is rescorified .	———
Average loss of gold in crucible slag	0.09 mgs.
Average loss of gold in per cent	.45%

These figures are based on the highest corrected assay in each case, that being taken as 100.

A set of assays was also run in which the heat of the fire and time in fire was varied, to determine whether these factors had any influence on the result. The fires varied from a red to a white heat, and the time from 30 minutes to one hour.

The difference in results was very small, and a good moderate fire, with from 40 to 50 minutes in the furnace gave the best results. Cupellation should, however, be carried on at a low heat.

SCORIFICATION ASSAYS.

Both ores No. 1 and No. 2 were run by scorification with but very indifferent results, one fact, however, being certain, that scorification for both high and low grade ore gave low results.

Ore No. 1 was first assayed by the following charge:

Ore 1/5 A. T.
Test Lead, 70 grams.
Litharge cover, 20 grams.
Borax glass, ½ gram.

This gave gold, 4.30 oz., against crucible method of 5.62 oz. The test lead was increased to 80 grams, giving gold 4.80 oz.

Then to still further increase the ratio of test lead to ore these charges (No. 1 and No. 2) were run.

No. 1.	No. 2.
Ore 1/10 A. T.	Ore 1/10 A. T.
Test Lead, 50 grams.	Test Lead, 60 grams.
Litharge, 20 grams.	Litharge, 20 grams.
Borax glass, ½ gram.	Borax glass, ½ gram.

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These were run in duplicate and gave the following result:

No. 1.	No. 2.
(a) gold = 4.20 oz.	(a) gold = 5.00 oz.
(b) gold = 4.00 oz.	(b) gold = 5.40 oz.

More assays were run by various charges, but invariably gave low results, much behind those of the crucible assay.

Ore No. 2 was run by the following charge:

Ore 1/10 A. T.

Test Lead, 50 grams.

Litharge cover, 20 grams.

Borax glass, ½ gram.

This gave gold 74.80 oz. (No. c.)

The test lead was increased to 60 grams giving gold 78.70 oz. (No. d.).

The scorification slags of these assays were ground up and remelted and gave the following results:

Recovered from No. c, 0.42 oz.

Recovered from No. d, 0.38 oz.

This makes the corrected result, figured to the assay ton: On No. c, 79.0 oz.; on No. d, 81.8 oz.

These corrected results are still way below the uncorrected values obtained by crucible assay. The loss of gold in the scorification slag is very great, but a greater loss takes place by volatilization.

These facts readily prove that the crucible assay is much the better for telluride ores.

Conclusions.

It is very evident that a large excess of litharge is necessary to obtain good results in assaying a telluride ore. The amount will vary with the richness of the ore, the proper proportion of litharge to ore being maintained in a rich telluride by decreasing the quantity of ore. A definite ratio of litharge to gold for telluride ores might be established.

The loss of gold in the crucible slag is many times more than that in assaying ordinary ores, and justifies the making of corrected assays when accuracy is required.

The loss of gold in cupellation which is recoverable, is not of much moment.

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Scorification of any kind is bad for a telluride ore, whether it be direct scorification of the ore, or the recorification of brittle or large buttons. The loss on cupelling a large or brittle button directly is much less than if it were first rescorified.

The amount of gold lost in the scorification slag when scorifying ore directly, is very great, amounting to 5.6% (page 424).

The highest uncorrected result also gives the highest corrected result, showing that loss takes place by volatilization.

The loss of gold in a rich telluride is greater than in a low grade ore, but the percentage of loss decreases with the richness of the ore.

In general, the crucible assay is best, by far, for telluride ores. The fire should be moderately hot, the length of time in the furnace, from 40 to 50 minutes. The assay should be conducted, so as to give a button of good size, from 20 to 28 grams, which can be cupelled directly. The cupellation should be made at a low heat with crystals of litharge forming on the cupel. When the assay is to be accurate, the crucible slag should be remelted and button cupelled and the resulting gold added to the first assay.

Mr. F. C. Smith published an article in the T. A. I. M. E., Vol. 26, p. 485, on "The Occurrence and Behavior of Tellurium in Gold Ores, etc.," which is partly devoted to the assay of tellurides.

His experiments tend to prove that the crucible assay is the better for tellurides, and that the loss of gold in the assay is very great if the charge is not properly made up as regards the amount of litharge present. He does not make corrected assays or locate the losses.

In the discussion of this paper, Mr. W. P. Jenney, states that he believes an oxidizing charge with small quantities of ore would be beneficial. The excess of PbO, of course, has this action, but to try this point further the assays on Table IV. were made by the following charge.

1/5 A. T. Ore.
4 A. T. PbO.
1½ A. T. Soda.
1 A. T. Silica.
20 grams Nitre.
6 loops iron wire.

The iron acted as reducing agent. The buttons were good size, malleable, but no increase in gold was noticeable.

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ABSTRACTS.

ANALYTICAL CHEMISTRY.

BY ELWYN WALLER, PH.D.

Filter Papers—Reducing Action.—Jervis (Ch. News, LXXVII., 133). The filtration of chromate solutions through paper causes a perceptible reduction of the CrO_3 as determined by testing against standard ferrous solution. Several papers were tried, each of which gave results slightly different from the others. The effects were most decided when the solution of CrO_3 was hot and acid. In the cold the reduction was in some cases nil.

Aluminum as an Electrode.—Hough (J. Am. Chem. Soc., XX., 302). Al can only be used as a cathode, being dissolved off when used as an anode. In sulphate or chloride solutions it could not be used at all. In HNO_3 solutions it appears to work well, and might be of service in Cu determinations. It can also be used in $KNH_4C_2O_4$ solutions such as are recommended by Cla-sen for certain depositions. Its use in KCy solutions is also possible.

Pure Copper for Analytical Work.—Westmoreland (Analyst, XXII., 86). Many, indeed the majority, of the samples of copper supplied by chemical dealers as "pure" were found not to be so, the amount of pure copper in them being in almost all cases something over 99 per cent. One sample contained only 94.42 per cent. Arsenic was found in several of the samples, in one case 0.67 per cent. Both the electrolytic and iodide methods were used in determining the Cu.

Alkalimetric Indicator.—Crismer (Report de Pharm., 1896, 208) recommends Resazurin $C_{12}H_7NO_4$. It is but slightly soluble in water, more so in alcohol, and readily so in acetic ether. Aqueous and alkaline solutions are blue. acid are red. For use dissolve 0.2 gm. in 40 cc. N/10 ammonia, and dilute to one litre; 2 or 3 drops of this solution suffice for a bulk of 200 cc. With HNO_3 it is not usable. Uncertain in presence of CO_2. The delicacy is extreme. The Resazurin is made by dissolving 4 gms. Resorcin in 300 cc. of (water free) ether, and adding 40 to 45 drops of HNO_3 (SpGr 1.25) saturated with HNO_2. After standing for two days the solution is poured off from the (brown) crystals, which are washed with ether until the washings are no longer colored blue by ammonia.

Volumetric for Sodium.—Fenton (J. Lond. Chem. Soc., LXXIII., 167). Sodium dihydroxytartrate ($Na_2C_4H_4O_8$) was found by this author to be quite insoluble in water, especially when cold. He has also found that $K_2Mn_2O_8$ oxidizes the dihydroxytartaric acid quantitatively. By precipitating a concentrated solution of sodium chloride, sulphate or nitrate with a saturated solution of potassium dihyroxytartrate (1 in 30) in ice cold solution, and filtering, the excess of the precipitant may be titrated and the Na thus determined. Metals other than K, Na and Mg must be absent. Also precipttaion does not occur in

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borax solutions. NH_4 salts seem to exercise some solvent action. The solution should be neutral for precipitation. The permanganate is best standardized by means of a standard solution of NaCl.

Potassium Determination.—Moore (J. Am. Chem. Soc., XX., 340). K may be determined without previous removal of Fe, Al, Ca, etc., by treating the *clear* solution of a mineral, soil, etc., after evaporating off excess of acid, essentially in the same manner as the treatment of the solution when all but alkalies have been removed. Add H_2PtCl_6 sufficient to combine with the K, evaporate low, then add *acidulated alcohol*, made by passing dry HCl gas into alcohol of 90 per cent. until 1 cc. of the same neutralizes about 2 ⅓ cc. of normal KOH. The acidulated alcohol removes Fe, Al, etc. The sulphates, NaCl, etc., must be washed out by NH_4Cl solution, 200 gms. per litre, as prescribed by Lindo. After washing with 85 per cent. alcohol pure K_2PtCl_6 is left.

Alumina in Bauxite.—Phillips and Hancock (J. Am. Chem. Soc., XX., 209). The manufacturer's requirements as to bauxite are as follows in the order of their importance:

1. Easy solubility of the alumina in H_2SO_4.
2. Rapid filtration.
3. Rapid washing.
4. Freedom from substances that on going into solution would affect the quality of the alum or other products. If the bauxite is ferruginous the fourth point may come second. The usual method of analysis has been to treat with a mixture of acids, finally evaporating down to fumes of SO_3 to determine extractable Al_2O_3. By a series of experiments it has been found that treatment with H_2SO_4 of 50° B. at 100° C. for one hour practically extracts all the Al present as $Al_2(OH)_6$. This it is proposed shall be called "Free alumina." Heating to fumes of SO_3 extracts more Al_2O_3, some of which apparently comes from the clay in the samples. This it is proposed to call "Combined alumina" and the sum of these two to be called "Available alumina." The method of analysis proposed is:

Moisture.—Dry 2 gms. to constant weight at 100° C.

Available Alumina.—2 gms. bauxite, 10 cc. cold H_2SO_4 of 50° B. Heat gradually in a casserole with stirring to fumes of SO_3, cover with a watch glass and heat for 10 minutes, cool, add 100 cc. hot water, boil 5 minutes, filter and wash. Cool, dilute to 200 cc. and take (*a*) 50 cc. for Al_2O_3, Fe_2O_3 and TiO_2, and (*b*) 50 cc. for TiO_2 and Fe_2O_3. Dilute (*a*) to 300 cc., add 2 cc. HCl, boil, add slightly excess of NH_4OH, boil 5 minutes, filter and wash thoroughly. Ignite and weigh mixed Al_2O_3, Fe_2O_3 and TiO_2, from which weight Fe_2O_3 and TiO_2 found in (*b*) is to be deducted.

Titanium oxide.—Dilute (*b*) to 350 to 400 cc. after neutralizing with NH_4OH, and then adding a slight excess of H_2SO_4; add SO_2 to reduce Fe and boil for one hour, keeping up the volume, and also adding SO_2 from time to time so that the odor is all the time decided. Filter hot, wash, ignite and weigh TiO_2.

Ferric oxide.—Reduce the filtrate from TiO_2 by Zn and titrate as usual.

Free Alumina.—2 gms. bauxite, 10 cc. H_2SO_4 of 50° B. in 4-ounce Erlenmeyer flask provided with perforated stopper; heat for one hour in a boiling-water bath, shake frequently, add 100 cc. hot water, and keep

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in the bath for 10 minutes. Filter, wash and treat as before, except that TiO_2 does not dissolve and, therefore, does not have to be determined. Weigh Al_2O_3 and Fe_2O_3 from one aliquot portion, and determine Fe in another.

For determination of SiO_2 total Al_2O_3, etc., fusion with $KHSO_4$ is recommended. TiO_2 is always present, sometimes to the extent of 4 per cent. A portion (50 to 75 per cent. or more) is soluble in H_2SO_4 concentrated to fumes.

Alumina and Ferric oxide in Phosphates.—Lichtschlag (Chem. Ztg. XXI., 264). Fuse 2 gms. with 8 gms. Na_2CO_3 for twenty minutes, cool, detach the cake, rinse out with HCl, which is used afterward to dissolve the mass in a beaker. Put solution into a 200 cc. flask—neutralize with NaOH, bring to boiling, and add 30 cc. of 20 per cent. NaOH solution. Heat 15 minutes, then cool and fill up to the mark. Filter off 50 cc. add excess of HCl, then a little Na_2HPO_4; boil, and precipitate out $AlPO_4$ by adding excess of ammonia.

The Fe_2O_3 precipitated out by the NaOH, may be dissolved, reduced by Zn and titrated.

Iron by Hydrogen.—Schmidt (per Rev. Chim. Anal. App., VI. [3] 32). 0.4 gm. of the sample is weighed out in a 100 cc. flask and 2 to 2.5 gms. of I (accurately weighed) are added, then 5 to 10 cc. of water. The action ensuing dissolves only the metal, leaving the oxide present. 1 gm. KI is then added and the excess of I titrated with standard $Na_2S_2O_3$.

Bichromate Titration—Influence of Manganese.—Jervis (Ch. News, LXXVII., 133). The presence of Mn salts in the solution interferes with the development of the blue-coloration (end reaction—spot test with $K_6Fe_2Cy_{12}$), when but little ferrous salt is present, and may prevent it altogether from being seen. Using very little solution of $K_6Fe_2Cy_{12}$ helps to avoid this interference, but somewhat impairs the delicacy of the reaction.

Chrome Steel Analyses.—Leffler (Ch. News, LXXVII., 156). In analyzing chrome steel by Galbraith's method, was found to give high results. The method consists in dissolving in H_2SO_4, adding $K_2Mn_2O_8$ to oxidize $FeSO_4$ to $Fe_2(SO_4)_3$ and Cr_2O_3 to CrO_3, filtering off precipitated Mn oxides, adding standard ferrous solution, and titrating the excess with standard $K_2Cr_2O_7$. The results were found to be higher in proportion to the amount of acid used for dissolving and the excess of $K_2Mn_2O_8$ used. Blank tests with steel containing no Cr, using the same amounts of acid and $K_2Mn_2O_8$ gave figures which when deducted from the apparent percentage found, gave results concordant with results obtained by Stead's modified $K_2Mn_2O_8$ method and Arnold's phosphate method.

Manganese in Plants and Soils.—Pichard (C. Rend, CXXVI., No. 7) applies the colorimetric method (forming $H_2Mn_2O_8$ by boiling with HNO_3 and Pb_3O_4 and making colorimetric comparison). The amount of material convenient to use (0.5 gm. or more) must be determined by a preliminary test. The material should be well pulverized and first incinerated at a dull red heat. (For plants the temperature of incineration should be somewhat higher than for soils.) The residue is mixed with two parts of Na_2CO_3 and calcined. After cooling it is detached by dilute HNO_3, and about 0.5 gm. Pb_3O_4 added. Then pour in 4 cc. H_2O and 2 cc. HNO_3, boil down to about one half, let stand and compare colors with standard treated in the same manner.

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Manganese Electrolytic.—Kaeppel (Zts. Anorg. Chem., XVI., 268). A firmly adherent deposit of MnO_2 was found to be obtained by addition of 1 to 10 gms. of acetone to the sulphate solution, and electrolyzing from 2 to 5 hours with a current of 4 volts and 0.6 to 1.2 amp. at 50 to 60° C. After washing the deposit was dried 1 to 2 hours at over 150°–180° C. From mixtures of Fe and Mn salts, the Fe was completely separated by adding a large excess of $Na_4P_2O_7$ (12 gms. to 1 of Fe salt) and a few drops (5) of H_3PO_4, leaving it still alkaline, and electrolyzing at 35°–40° C. for 8 or 9 hours. 4 volts 1.5 to 2.5 amp.

Separation of Arsenic.—J. and H. S. Pattinson (J. S. C. I., XVII., 211). The methods described depend on the insolubility of As_2S_3 in strong HCl (Sp. Gr. 1.16 to 1.17) when saturated with H_2S. Sulphides of Pb, Cd, Sn, Sb, and Bi are entirely soluble in acids of this strength. The As must be in triad form, which may need to be completely induced by addition of $SnCl_2$. When dissolved in alkaline sulphide the tendency to assume the pentad form is quite pronounced, and the solution should be exposed to the air as little as possible. To insure complete saturation of the acid by H_2S, the addition of ZnS may in some cases be necessary. The As_2S_3 (separating by filtering through asbestos) may be dissolved by heating with conc. H_2SO_4, the heating being prolonged until all SO_2 is entirely expelled, and may be titrated with standard I solution after dilution.

Tin in Tin Plate, etc.—Job. (J. S. C. I., XVII., 325). A piece of the tin plate 4 inches square is cut from the centre of a sheet taken at random from the box (112 sheets 20 x 28 in.). Put 100 cc. CPHCl (Sp. Gr. 1.20) in a graduated 200 cc. flask to which is fitted a cork with Bunsen valve. Drop in a piece of marble (about 5 gms.). Insert the cork and let the flask stand for about 5 minutes. Meantime cut the 4-inch piece into strips suitable for insertion in the flask. Remove the cork, drop in the strips quickly and replace the cork. Heat to hasten the action, and when the plate is nearly dissolved drop in another piece of marble and close again. The moment the plate is entirely dissolved, while effervescence still comes from the marble, cool as rapidly as possible until the solution is ice cold. Remove the cork, and add ice water to the mark, pouring down the side. Stopper tightly and mix well. Then by means of a pipette transfer 50 cc. to an 8 oz. Erlenmeyer flask, add a little starch and titrate with standard I. solution. (That used by the author 1 cc. = 0.000560 gm. Sn. It is standardized once a week.)

Run into another flask the amount of I solution used, and add to it another 50 cc. of the solution dipping the end of the pipette below the surface until just at the end of the delivery. Add a little starch, and finish in the ordinary manner, with a little more of the I solution. From the result calculate Sn per spuare inch, and this number × 0.98 gives weight of tin in pounds per box of 112 sheets (20 x 28 in).

Estimating Tin in Stannic Salts.—Fraenkel and Fasal (Chem. Ztg. Rep. 1898, 11). The Sn is precipitated out in metallic form by use of metallic Al in HCl solution. It may be afterward dissolved up in HCl, and titrated with standard I solution.

Estimation of Tin.—J. and H. S. Pattinson (J.S.C.I., XVII., 214). $Sb_2(SO_4)_3$ is completely insoluble in cold conc H_2SO_4 (SpGr 1.83) when cooled. Brought into solution by boiling in the acid, it separates completely in white crystalline form on cooling. This precipitate may be

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separated by filtering through asbestos. On diluting, neutralizing with ammonia and adding $(NH_4)_2$ S. As and Sn go into solution from which they are precipitated by acidifying with diluted H_2SO_4 (1 to 3 by vol.). The sulphides are dissolved by boiling with HCl containing Br. Decant from separated S, which is afterward oxidized up by fuming HNO_3 and the solutions united. Clarke's method (oxalic acid in H_2S solution) is then applied. The Sn which remains dissolved, is precipitated out by neutralizing with ammonia adding $(NH_4)_2S$, and finally acidifying with acetic acid.

Lead in Drinking Water.—Liebrich (Chem. Ztg., XXII., No. 24). If the water is acidified with $HC_2H_3O_2$, evaporated to small bulk, and treated with H_2S, treatment of the precipitate (with HNO_3 and H_2SO_4) to convert to $PbSO_4$ and weighing, gives high results on account of the impurities accompanying the PbS. Treating the impure $PbSO_4$ with a little KOH solution, filtering and diluting to 20 cc. affords a solution in which colorimetric comparisons can be made with solutions containing known amounts of Pb. Add to each 2 cc. of a freshly prepared solution of $(NH_4)_2S$. The PbS obtained may again be converted into $PbSO_4$ and weighed if a check is desired.

Separation of Mercury from Bismuth.—Vanino and Treubert (Berichte, XXXI., 129). The solution containing these metals should be weakly acid. To this is added excess of a solution made up in the proportion of one drop of commercial hypophosphorus acid to 1 cc. of H_2O_2. Hg_2Cl_2 separates quantitatively, filter, wash with *cold* water, dry at 105° C. and weigh. Heat the filtrate to expel free HCl and decompose H_2O_2. Then render slightly alkaline with NaOH. Again add HH_2PO_2, and heat over a naked flame, with frequent stirring, until the black precipitate of metallic Bi has completely separated and the solution shows no cloudiness by diluting with water. By means of a rod compress the metallic sponge into a compact mass, filter on a weighed filter, wash, dry at 105° C. and weigh.

Separation and Estimation of Lead, Copper and Arsenic.—Jean (J. Pharm. Chim., VII., No. 5). Precipitate by H_2S from HCl solution, wash the sulphides by decantation, treat them with a little KClO, followed by H_2SO_4, boil out Cl, add alcohol and filter off $PbSO_4$ for determining Pb. Render the filtrate ammoniacal to an extent sufficient to give a clear solution and determine Cu by titrating with standard Na_2S. Acidify with HCl and filter out CuS, add $KClO_3$ and boil down to about 20 cc., nearly neutralize with ammonia, add 5 cc. $NaC_2H_3O_2$ and titrate As_2O_5 with standard uranium solution.

Yttria Earths of Monazite and Æschinite.—Fractional crystallization Urbain C. Rend., CXXVI., No. 11). The ethylsulphates prepared by doublie decomposition between the yttric sulphates and barium ethylsulphate have afforded the best results. The separation is in this order: Yttrium, terbium, holmium and dysprosium erbium, ytterbium.

Incandescent Mantles.—Welsbach light, etc. Hintz (Fres. Zts. Anal. Chem., XXXVII., 94). Cerium may be volumetrically determined in presence of large amounts of Th by means of Gibbs reaction (with H_2O_2) by exercise of special care. Practise is necessary to attain trustworthy results. The Ce solution must be acidified with dilute H_2SO_4 to an extent sufficient to prevent precipitation of $Ce_2(SO_4)_3$ on boiling. Cool, add ammonium persulphate $[(NH_4)_2S_2O_7]$ and boil for one or two

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minutes to peroxidize Ce. Cool to 40–60° C. by standing in cold water, add a second portion of $(NH_4)_2S_2O_7$ and heat to boiling for a few minutes again. Repeat this operation of cooling down, etc., making the duration of the final boiling 5 to 15 minutes. Toward the end of the boiling add a little more dilute H_2SO_4 to decompose the excess of $(NH_4)_2S_2O_7$. About 3 gms. $(NH_4)_2S_2O_7$ serves for 0.3 gm. Ce. About one-half of this is added for the first boiling, and one-fourth each for the second and third. Thoroughly cool the solution which now contains all the Ce as CeO_2, run in from a burette a standardized (dilute) solution of H_2O_2 until decolorization is complete, and titrate back the excess of H_2O_2 by standard $K_2Mn_2O_8$. The latter may be standardized by $FeSO_4$, 56 of Fe correspond to 140 of Ce or to 172 of CeO_2. Too large an excess of free H_2SO_4 gives low results, so that it is advisable before titrating to *partially* neutralize the free acid. Photometric tests tend to show that mantles containing 99 parts of ThO_2 to one of CeO_2 are unaffected as to lighting power by the presence of up to one per cent. of neodymium, lanthanum or yttrium oxides, or of 0.2 to one per cent. of ZrO_2. The effect of 0.1 per cent ZrO_2 is somewhat in doubt. The presence of CaO is detrimental causing, rapid disintegration of the mantles.

To examine mantles at least a dozen should be taken, and the upper and lower ends cut off and rejected. After weighing extract completely with water acidulated with a few drops of HNO_3. Incinerate the remainder, fuse with $KHSO_4$, dissolve in water and HCl, precipitate with ammonia, and add the HNO_3 solution of the principitate to the first solution, and bring the whole to a definite volume. In certain cases a special test for neodymium can be made on the concentrated nitrate solution with the spectroscope. The absorption bands are readily seen when under one per cent. is present.

1. In an aliquot portion after evaporating off excess of acid, precipitate with $H_2C_2O_4$. Filter and wash on a toughened filter. Rinse off into a beaker, heat with conc. solution of $(NH_4)_2C_2O_4$, dilute, cool, and let stand some time before filtering. Ignite and weigh precipitate. If the weight of the precipitate is not more than 1 per cent. *more* than the CeO_2 (found by titrations above) the Nd, La and Yt oxides are not present in proportions sufficient to affect the illuminating power of the mantles. If the reverse is the case, dissolve weighed precipitate in the crucible with H_2SO_4 and heat, neutralize with amonia, precipitate with $(NH_4)_2C_2O_4$, etc.

Test the filtrate for ZrO_2 by evaporating, igniting to decompose oxalates, dissolve in HCl, and after driving off free acid test micro-chemically, thus: Evaporate a drop of the aqueous solution on a microscope slide, then add a drop of water, and a drop of KHC_2O_4 solution, dry off, and examine with the microscope for the characteristic crystals of potassium zirconium oxalate.

2. In another aliquot portion evaporate off free acid, precipitate with $H_2C_2O_4$ and ignite and weigh the mixture of oxides, ZrO_2 excepted.

3. In another portion titrate Ce, as already described.

Separation of Thorium.—Wyrouboff and Verneuil (C. Rend., CXXVI., No. 4). To obtain pure ceriun salt it is sufficient to dissolve a precipitate of mixed Ce and Th oxides in enough HCl to reduce the Ce to CeO, add a little H_3PO_4 and evaporate to pastiness, take up with

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water and filter. All the Th and a little of the Ce remain in the insoluble portion, while the solution contains only Ce.

A modification of Cleve's reaction (adding H_2O_2 to Th (SO_4), which affords gelatinous $Th_4O_7.SO_3$) was found effective in this way: Having a solution of Th $(NO_3)_4$ containing a minimum of free acid, the addition of H_2O_2 in excess, and heating to about 60° precipitates the whole of the Th. If much Ce is present, small amounts will remain in the precipitate. By dissolving in HNO_3 evaporating to dryness, diluting and again using H_2O_2, much or all the Ce remaining may be removed. A third precipitation may, however, be necessary. The precipitate cannot be calcined or dissolved in HNO_3 directly without loss from the vigorous escape of O. The mode of treating the precipitate serving to avoid this difficulty was as follows: After washing until the wash water gave no precipitate with ammonia, the precipitate was detached from the filter, and dissolved in a little water containing 2 gms. NH_4I and 2cc. conc. HCl. The hot solution is run through the filter to dissolve adhering particles, which filter is then washed. From the solution ammonia will precipitate Th $(OH)_2$ which can then be dissolved or calcined without mechanical loss. The reaction described by Dennis (vid QUARTERLY XXIII., 173) with potassium hydronitride does not afford a complete separation from Ce.

Tellurium-Iodometric method.—Norris and Fay (Am. Chem. J., XX., 278). In presence of a large excess of alkali, dilute and cold, the reaction between TeO_2 and $K_2Mn_2O_8$ is this:

(1) $2KMnO_4 + 3TeO_2 = K_2O + MnO_2 + 3TeO_3$.

In acid solution the reactions of MnO_2 and $KMnO_4$ respectively are:

(2) $2MnO_4 + 4KI + 4H_2SO_4 = 2MnSO_4 + 2K_2SO_4 + 4H_2O + 4I$.

(3) $2KMnO_4 + 10KI + 8H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 10I$.

The oxidation of TeO_2 by $KMnO_4$, followed by acidification, and addition of KI may be expressed thus:

(4) $2KMnO_4 + 3TeO_2 + 4KI + 5H_2SO_4 = 3TeO_3 + 3K_2SO_4 + 2MnSO_4 + 5H_2O + 4I$.

A determination of the I set free by a known amount of $KMnO_4$ solution, as compared with the amount of I set free after a portion of the oxidizing power of the $KMnO_4$ has been expended in oxidizing TeO_2 affords a basis for the rapid and accurate estimation of the Te.

The standard solutions used are $Na_2S_2O_8$ approximately tenth normal $KMnO_4$ 7 gms. per litre.

The TeO_2 solution is treated with 20 cc. of a 10 per cent. solution of NaOH. Standard $KMnO_4$ is then added from a burette until the solution shows a deep pink color. This mixture is then diluted with ice water, acidified with H_2SO_4, 2 gms. of KI in solution added, and titrated with the standard $Na_2S_2O_8$. The deficit in the amount of $Na_2S_2O_8$ required in this case as compared with the amount necessary when the TeO_2 is not present affords a measure of the Te.

Perchlorate in Chili Saltpetre.—Selckmann (Zts. Angew. Chem., 1898, 101). The amount of chloride in the sample is first determined. Then 5 to 10 gms. of the sample are placed in a porcelain crucible of 40 to 50 cc. capacity and 3 or 4 times the weight of Pb. in chips added, and heat is applied gradually. The salt fuses first, then the Pb. and reaction between them begins, shown by evolution of gas and formation of PbO.

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By use of a hooked Cu wire fresh metallic surfaces may be brought in contact with the salt. The heat should be regulated so as to avoid too rapid a reaction. When the melt becomes thick and gas no longer escapes, which occurs in about 10 minutes after beginning of fusion, the heat is raised a little until the bottom of the crucible is at dull red, at which point it is maintained for one or two minutes to complete the reaction. Too strong heating which will fuse the $PbCl_2$ or PbO must be avoided. Then cool the melt and leach out with water in a beaker. Reddish PbO and small globules of Pb should only remain undissolved. If the heat has been too high, yellow oxychloride is present. In that case it is better to dissolve it in a solution of 2 to 3 gms. of $NaHCO_3$ or in NaOH. In any case the Cl should be determined in the solution gravimetrically, as the nitrite present does not permit of accurate titration.

Determining Phosphine in Acetylene Gas.—Hempel and Kahl (Zts. Angew. Chem., 1898, 53). Acetylene prepared from CaC, is dangerous if it contains PH_3. To determine this impurity a series of experiments were made, the results of which showed that the best absorbent for PH_3 was a solution containing 15.6 gms. crystallized $CuSO_4$ in 100 cc. of water, to which was added 5 cc. of diluted H_2SO_4 (1:4 by vol.). This should be used saturated with C_2H_2 and in contact with metallic Hg. After 3 minutes agitation in contact with the gas, standing, etc., one-fourth of the diminution in volume represents the volume of PH_3 originally present.

Aluminum Phosphides.—Analysis Franck (Fres.Zt s. Anal. Chem. XXXVII., 173). The best solvent is dilute H_2SO_4(1:2). The phosphide is dissolved in a flask, and the evolved gases are passed through a series of three bottles containing solution of HCl saturated with Br (about 20 cc. in each). The whole apparatus is filled with CO_2 gas during the operation. Something under 0.5 gm. of the phosphide is taken, placed in the flask, 50 cc. of water added, and CO_2 passed through the whole apparatus for 15 minutes, then through a globe stop-cock funnel tube 50 cc. of the diluted H_2SO_4 is gradually run in. After standing half an hour the contents of the flask are boiled for half an hour. A Bunsen valve is placed between the generating flask and the first absorption flask. After the operation the contents and rinsings of the flasks are evaporated in a porcelain dsh to dryness, the residue taken up with HNO_3 and the P_2O_5 determined in the usual manner. With an apparatus arranged as shown by the illustration in the paper, the author states that the third absorption bottle has never yet shown that any P reached it.

Phosphoric acid.—Weighing as Phospho-Molybdate. Gladding (Ch. News, LXXVII., 32). The varied results obtained by analysis of the "yellow precipitate" has usually prevented determination of P_2O_5 in this manner, except where the amounts were very small. By the method of treatment below, a precipitate having the constant composition $48MoO_3$, $2P_2O_5$, $10NH_3$, $11H_2O$ was obtained, which was weighed on a tared filter, and afforded accurate results with fertilizers and substances containing 15 to 20 or more per cent. P_2O_5.

To the solution containing the P_2O_5 (25 to 50 cc.) are added 25 cc. of strong ammonia (Gr. 0.900) and then HNO_3 (Gr. 1.42) to acidity. The beaker is then put in a water bath kept at 50° C. and the ordinary 5 per cent. molybdate solution added slowly from a burette (3 drops per second) with constant stirring. When about 10 cc. excess of molybdate

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has been added, the beaker is allowed to stand 10 minutes in the bath. The solution is then filtered through a weighed filter, and washed with dilute HNO_3 (1 in 100) three times by decantation, and three times on the filter, and a final washing with distilled water. An air bath is unsuited for drying this precipitate. A water oven may be used for preliminary drying, but for final drying one needs a glycerol oven containing glycerol SpGr. 1.16, boiling at 110° C.

Basic Slags, Citrate Soluble Phosphoric Acid.—Böttcher (Chem. Ztg., XXI., 168). On adding a sufficient amount of Mg mixture to the Werner $(NH_4)_3C_6H_5O_7$ solution from the slags, and agitating in a shaking apparatus for half an hour, the P_2O_5 is completely precipitated. The solution must be filtered at once, since by standing some SiO_2 will also separate.

Boric Acid.—Gladding (J. Am. Chem. Soc., XX., 288). The material containing the B_2O_3 is rinsed into a 150 cc. flask with some 95 per cent. methyl alcohol, and 3 cc. of an 80 per cent. (syrupy) solution of H_3PO_4. The flask is connected on the one side with a condenser and receiver, on the other with a flask of boiling methyl alcohol (in a water bath) the vapors being delivered by a tube at the bottom of the liquid in the flask containing the material. The heat applied to this flask is so regulated that the liquid is kept at a bulk of 15 to 25 cc. In about 30 minutes about 100 cc. should have distilled over. To this is added a carefully neutralized mixture of 40 cc. glycerin with 100 cc. water (phenolphthaline indicator), and the whole is titrated with standard NaOH. Distil more to ensure the complete removal of the B_2O_3.

Sulphide and Sulphydrate of Sodium.—Dobriner and Schranz (Zts. Angew. Chem., 1897, 455). Dissolve 12 gms. of the (commercial) sample in 1 litre and run about 25 cc. of the solution from a burette, into 48 cc. of a twentieth normal I solution acidulated with 10 cc. normal H_2SO_4, and diluted up to 180 cc. If the yellow color of the solution does not disappear, repeat the experiment, using less of the N/20 I solution. Then add a little starch solution and titrate the excess of H_2S by the I solution.

In another portion of 6 gms. of the sample dissolved in water, determine Na by adding excess of normal H_2SO_4, boiling out all H_2S, and titrating back by normal alkali. The proportion of $Na_2S.9H_2O$ and of $2NaHS.9H_2O$ or of NaOH and $Na_2S.9H_2O$ may then be calculated.

Interaction of Thiosulphates with Cyanides.—Dobbin (Ch. News, LXXVII., 131). In concentrated solution after a time sulphites and thiocyanates, are formed thus: $K_2S_2O_3 + KCN = K_2SO_3 + KCNS$.

Carbon in Irons.—Harbeck and Lunge (Zts. Angew. Chem., 1898, 395). find that on treating pig iron etc., with Cu solution to dissolve the iron, some hydrocarbons escape. With $CuSO_4$ on an average 0.027 per cent. C is lost, with $2NH_4Cl$, $CuCl_2$ 0.015 per cent. of C is lost, using 5 gms of the iron. The method found to be satisfactory was that of Lunge and Marchlewski (Zts. Angew. Chem., 1891, 412), in which 5 gms. of the sample is treated with $CuSO_4$ solution in a closed flask through which a current of air free from CO_2 is passed, the air being afterward drawn through a tube filled with CuO and kept at red heat during solution and finally through weighed potash bulbs suitably charged. CrO_3 and H_2SO_4 are then added, and the remaining C is oxidized and caught in the potash bulbs. The introduction of a Pt spiral into the flask prevents bumping during the operation.

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Calcium carbide.—Testing-Bamberger (Zts. Angew. Chem., 1898, 196). The apparatus resembles in appearance the Schrötter CO_2 apparatus. Its capacity is about 400 cc., with on the one side a stop cock dropping funnel ground to its seat in the neck of the (double tubulated) flask, and on the other side fitted to the second tubulure a drying tube containing lumps of $CaCl_2$. The dropping funnel is filled with a 15 to 20 per cent. solution of NaCl, and 50 to 60 gms of the carbide charged into the flask. The NaCl solution is then allowed to drop slowly upon the carbide, until the whole has been decomposed, the C_2H_2 escaping through the drying chamber. The remainder of the NaCl is then run in rapidly, the apparatus warmed, and a current of air drawn through it. The yield of C_2H_2 is then determined by loss of weight. Theoretical yield of pure CaC is 40,625 per cent.

Carbonic acid in Sodium Bicarbonate.—Lunge (Zts. Angew. Chem., 1897, p. 422). By heating about 0.85 gm. of the sample in vacuo up to about 260° and conducting the evolved gas into a gas volumeter, the second molecule of CO_2 may be expelled and measured. 1 cc. of $CO_2 = 7.5124$ mgms. $NaHCO_3$. The mode of constructing and using the tube is carefully described. Heating for 10 minutes suffices, after which the apparatus must be allowed to cool for 10 minutes before measuring the gas.

Analysis of Silicates.—Leclere (C. Rend., CXX., 893). To avoid the difficulties involved in the obtaining of SiO_2 in the gelatinous form, the silicate is fused with three times its weight of PbO. After cooling, the mass is treated at 40° C. with (at least) ten times its weight of a mixture of equal parts of ordinary and of fuming HNO_3, afterward diluted with boiling water and filtered. Only the SiO_2 of the mineral remains insoluble.

Colorimetric for Silica in Waters.—Jolles and Neurath (Zts. Angew. Chem., 1898, 315). The alkaline molybdates give a yellow coloration with dissolved SiO_2 is presence of HNO_3. The potassium silico molybdate has the strongest color, which is most intense when the temperature of the solution is at about 80° C. The reagent is prepared by dissolving K_2MoO_4 in the proportion of 8 gms. in 50 cc. of water, and adding 50 cc. of C. P. HNO_3 of Sp. Gr. 1.2. The comparison solutions are prepared by diluting a solution of water glass (in which the SiO_2 has been accurately determined to such an extent that one has a set of solutions containing respectively in 20 cc. 0.00001, 0.00004, 0.00006, 0.00008, 0.0001, 0.0002, 0.0004, 0.0006, 0.0008 and 0.001 gm. of SiO_2. The comparison test tubes should be of such calibre that 20 cc. will have a depths of about 18 cm. 20 cc. of the water to be tested is taken, 1 cc. of the reagent added to it, and also to 20 cc. each of the comparison solutions, and the tubes immersed in a water bath which is heated to 80°. The depths of color are then compared. Good approximate results are readily obtained. The presence of arsenic is rather a remote contingency. That of phosphates, however, may in some cases cause error. In such contingency a color comparison on the raw water, and another test on the solution obtained after evaporating down with HNO_3 to remove SiO_2 and dissolving up, will afford a correction to be applied to the first reading.

Coal Analysis.—Report of Committee (J. Am. Chem. Soc., XX., 281). This report is only preliminary and tentative, criticisms and the record of experiments being invited.

1. *Sampling.*—At least five pounds is the amount recommended,

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which should be broken up, quartered, etc., as rapidly as possible, the final sample being well pulverized.

2. *Moisture.*—Dry one gm. in an open porcelain or Pt. dish at 104° to 107° for one hour, best in a double walled bath containing pure toluene, cool in a desiccator and weigh covered. Experiments recorded as to comparative results by this method, and by drying over H_2SO_4 showed a somewhat larges loss over H_2SO_4. Experiments as to loss of volatile matter along with the moisture tended to show that this loss was less than 0.1 per cent and may usually be disregarded.

3. *Volatile Combustible Matter.*—Place one gm. fresh undried coal in a platium crucible (20 to 30 gms.) having a tight fitting cover, heat over the full flame of a Bunsen burner for seven minutes. Crucible should be supported on Pt. triangle, bottom 6 to 8 cm. above the burner. Flame should be 20 to 30 cm. high when burning free, and determination should be made in a place free from draughts. Upper surface of the cover should burn clear, but under surface should remain covered with carbon. Loss is moisture and volatle combustible matter.

4. *Ash.*—Burn the portion of coal used for determining moisture at first over a very low flame, with the crucible open and iuclined, till free from carbon. This is more rapid than burning the coke to ash.

5. *Fixed Carbon.*—Obtained by difference in the ordinary manner.

6. *Sulphur.*—No recommendations made. Inquiries are made as to the methods used.

7. *Heating Effect.*—Should be calculated on coal burned to CO_2 and H_2O (vapor) at 100° C., and stated either in calories per kilo or English heat units per pound. Theoretical evaporative effect calculated by dividing calories per kilo by 536 or English heat units per pound by 96.5.

Heating effect within two per cent can be calculated thus: Subtract from 100 the per cent. of moisture and ash, and one-half the per cent. of sulphur, and multiply the remainder by 80.7, the product will be heating effect expressed in calories.

Test for water.—Brooks (Chem. News, LXXVII., 191). The salt $PbI_2.2KI$ is white but decomposes in presence of water, affording yellow PbI_2. To prepare it 1 gm. $Pb(NO_3)_2$ is dissolved in 10 cc. of water, and saturated solution of KI added until the precipitate just dissolves. Then, by standing a few minutes, a copious crystalline precipitate of the salt occurs. Pour off the supernatant liquid and shake the precipitate for a few minutes with 10 cc. of absolute alcohol. Pour it off, dry it rapidly with filtering paper, and preserve in a stoppered bottle over $CaCl_2$. The mother liquor can be utilized for another crop of crystals by adding a little more $Pb(NO_3)_2$. The substance is more sensitive than anhydrous $CuSO_4$ for tests as to the anhydrous condition of absolute alcohol, ether, chloroform, etc. Though decomposed by water it dissolves in saturated KI solution. When heated it becomes temporarily yellow.

Sulphuric Acid and Lime in Waters.—Robin (J. Pharm. Chem. [6], VII., No. 6). 100 cc. of the water is boiled in a flask (after addition of 0.5 to 1 cc. of a solution of Na_2CO_3 and NaOH), for about 5 minutes, cooled and filled up to the mark. After mixing, 50 cc. is filtered off, acidified with 5 to 10 drops of HCl, and after boiling to expel CO_2 it is just neutralized with ammonia and 10 cc. of twentieth normal $BaCl_2$ solution added. After boiling for a short time allow to stand for 15 minutes. Then add 10 cc. twentieth normal chromate (3.69 gms.

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$K_2Cr_2O_7$ dissolved, rendered alkaline with ammonia and then diluted to 1 litre) and boil. Cool, filter, and determine excess of chromate by standard ferrous solution. Telle (ib. No. 4) gives the same method, using KI and $Na_2S_2O_3$ to estimate the excess of chromate. The lime which remains on the filter from the first operation (boiling with Na_2CO_3 and NaOH) is dissolved through by moistening with HCl, and washing with water. After rendering the solution alkaline with ammonia 10 cc. deci-normal $(NH_4)_2C_2O_4$ solution is added, it is made up to 100 cc. and after shaking is allowed to stand for at least 30 minutes. The lime can then be estimated by permanganate titration either of the oxalic acid in the precipitate, or the excess of oxalate in the solution.

Testing Paints.—Loesner (per Analyst., XXIII., 77). To determine the permeability a piece of polished sheet iron (2 x 4 in.) is painted with two coats of the paint, the first coat being dried on before the second is applied. The iron is then supported at 2 inches above the surface of the water in a boiling (constant level) water bath. After 15 hours of steaming, and drying at 100°, the paint is removed by aniline, and the surface of the iron examined for rust. Sheet iron strips prepared in the same way may be similarly exposed to the fumes of 33 per cent. HCl at 20° C. for 12 hours to determine resistance to acid fumes. Any incrustations forming on the surface should be removed from time to time by washing with water. Fats, laquers, etc., require only a four-hour test conducted in the manner described.

Sulphur Monochloride.—Action on minerals. Smith (J. Am. Chem. Soc., XX., 289). The liquid was poured over some of the pulverized mineral in a glass tube from which the air was then expelled by CO_2 and the tube was sealed. The action in the cold was noted, and where decomposition did not occur at all, or only partially, the tube was heated. Complete decomposition occurred in the case of most of the sulphide minerals. Molybdenite was not completely decomposed even after heating to 300° C. Rutile, wolfranite, scheelite and columbite are all decomposed. With sulphides of the non-metals the decomposition was violent and complete without the application of heat.

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF METALLURGY.

With the incoming of Professor Howe to the Chair in Metallurgy, a radical change was made in the instruction given by the Department.

The subject of Metallurgy is so broad and comprehensive that the lectures were divided, Professor Howe lecturing on the metallurgy of copper during the months of October, November and December and on the metallurgy of iron and steel during the balance of the year. Dr. Struthers delivered the lectures on general metallurgy during October, November and December, and lectured on the metallurgy of lead, gold, silver and the minor non-ferrous metals during the rest of the year.

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Practical instruction in the metallurgical laboratory was given during the entire year to the students in the course of metallurgy, and students in other departments have done considerable furnace work in our laboratories.

In July, 1897, the second year of the summer school in practical metallurgy was held at Chicago, Pittsburg and environs, under charge of Dr. Struthers. The subject of the manufacture of iron and steel was chosen for study and the works of the Illinois Steel Company and the Carnegie Steel Company, together with several others, were visited and carefully studied. The changes recommended by the Committee on the Course in Metallurgy will go into effect during the coming year. In brief, these changes are as follows: The course in metallurgy will be changed so that a greater difference will exist between it and the course in Mining Engineering; to that end more instruction will be given in Chemistry and Electrical Engineering and less in Mining and Mechanical Engineering than hitherto.

The additions made are chiefly instruction in rapid methods of analysis, such as are in actual use in laboratories of metallurgical works, in gas analysis, in the calorimetry of fuels, in electro-chemistry and electro-metallurgy. To make room for these additions several courses in mining engineering, mechanics and mechanical engineering will be omitted.

Through the kindness of a friend, the metallurgical furnace room will be equipped with several furnaces to be used on an illustrative scale and other much needed apparatus.

Dr. McIlhiney has resigned from the position of assistant in metallurgy but will remain in the Department as an honorary fellow. Mr. R. S. McCaffery, of the class of '96, School of Mines, has been appointed to the assistantship. The students of the Schools of Mines and Chemistry attending the lectures in Metallurgy visited several smelters and foundries under direct charge of the Department. The works of the Nichols Chemical Company, at Laurel Hill, N. Y.; the Guggenheim Smelting and Refining Company, at Perth Amboy, N. J.; and the foundry of the Worthington Pump Company, at Elizabethport, N. J., were visited and studied. The students of the School of Mines also visited the works of the Bethlehem Iron and Steel Company, at Bethlem, Pa., with the class in mechanical engineering.

The department has been favored by many gifts of specimens of metals and products of their manufacture for the collection and for use in the laboratories of the Department. Professor Thomas Egleston has recently given the Departmental Library more than a hundred volumes of standard metallurgical works. The Departmental Library, which was started this year, has already shown its efficiency by the number of students in attendance. Nine new advance courses on metallurgy have been offered and a large num berof new diagrams have been made. Special work, publications and investigations by members of the Department are detailed as follows:

By Prof. H. M. Howe:

PUBLICATIONS.—"The Connection Between the Hardening Power and the Retardations of Low Carbon Steel," *Engineering and Mining Journal*, Vol. LXIV., Sept. 25, 1897, p. 367, and *Engineering* (London), Vol. LXIV., Oct. 22, 1897, p. 514. "Note on the Use of the Tri-Axial

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Diagram and Isometric Tetrahedron for Graphic Illustrations." "Transactions of the American Institute of Mining Engineers, Vol. XXVII. (to appear).

INVESTIGATIONS.—Also the following investigations, the results of which are not yet published: (1) "On the Melting Point of Extra Fusible Cast-irons." (2) "On the Hardening of Nickel-steel." (3) "On the Distribution of the Effects of Hardening in the Different Layers of a Bar." (4) "On the Hardening of Nearly or Quite Carbonless Iron, Copper and Platinum in Melting Mercury and Melting Alcohol."

By Joseph Struthers, Ph.D.:

SPECIAL WORK.—In charge of the Summer School in Practical Metallurgy at Chicago and Pittsburg, July, 1897. Students of the School of Mines in attendance. Subjects studied: The Manufacture and Working of Iron and Steel.

PUBLICATIONS.—"Abstracts and Note References in Metallurgy for the Year, 1897," SCHOOL OF MINES QUARTERLY, April, 1898, Vol. 19, No. 3. "Fuel and Refractory Materials," A. Humboldt Sexton (Review), SCHOOL OF MINES QUARTERLY, Nov., 1897, Vol. 19, No. 1. "The Stamp Milling of Gold Ores," T. A. Rickard (Review), SCHOOL OF MINES QUARTERLY, Nov., 1897, Vol. 19, No. 1. "The Mineral Industry," Volume V, edited by R. E. Rothwell (Review), SCHOOL OF MINES QUARTERLY, Nov., 1897, Vol. 19, No. 1. "Notes on Lead and Copper Smelting and Copper Matte Converting," H. W. Hixon (Review), SCHOOL OF MINES QUARTERLY, Nov., 1897, Vol., 19, No. 1.

INVESTIGATIONS.—"On the Study of the Cooling Curves of Metals and their Corresponding Temperatures," with Mr. G. C. Henning.

By P. C. McIlhiney:

Papers read before the American Chemical Society on "Some Experiments in Thermo-Electric Pyrometry" and "A Method of Determining the Resistance of Electrolytes."

BOOK REVIEWS.

Elements of the Differential and Integral Calculus with Applications. By WILLIAM S. HALL, Professor of Technical Mathematics in Lafayette College. D. Van Nostrand Company, New York. 1897. 8vo, pp. xi + 249 with 44 figures.

This work is an introduction to the study of the Differential and Integral Calculus and is intended for colleges and technical schools. In the first few chapters the student's attention is concentrated upon the derivative and the fundamental formulas are deduced strictly by the method of limits. Differentials are then introduced, being defined as infinitely small increments. The method of infinitesimals is said to differ only in phraseology and notation, from that of limits.

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As soon as the fundamental formulas of differentiation have been established, the corresponding inverse operations or integrations follow. This emphasizes the fact of integration being merely the inverse of differentiation, rendering the whole subject, it seems, more intelligible besides saving much time and space.

The remainder of the book touches upon the usual subjects treated in the ordinary calculus text-book but in a rather clear and forcible manner.

The special points in favor of the book are:—

1. The use of the symbol ∂ to denote partial differentiation. This in the practical application of the calculus is an immense aid.

2. Many of the numerical problems illustrating the text show actual applications in engineering practice. This renders the book especially useful to engineers and engineering students.

3. A table of integrals arranged for convenience and reference forms an appendix of twelve pages.

4. It contains a chapter on Differential Equations which distinguishes the work from any other text-book on the subject of the calculus. This addition is particularly valuable to engineering students, especially those in electrical engineering, and gives them information which, heretofore, they were compelled to seek in more advanced courses and at much more labor and greater expenditure of time.

The work is certainly what the author claims for it and shows much care and thought in its preparation as well as a complete understanding of the needs of an engineering student.

W. H. F.

THE SCHOOL OF ARCHITECTURE IN ITS NEW QUARTERS.

By PROFESSOR WILLIAM R. WARE.

PLATES.

(The plates on the following pages were omitted in the April number of this volume of the QUARTERLY by misunderstanding.—ED.)

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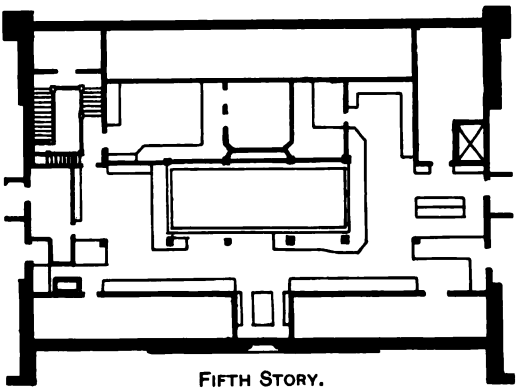

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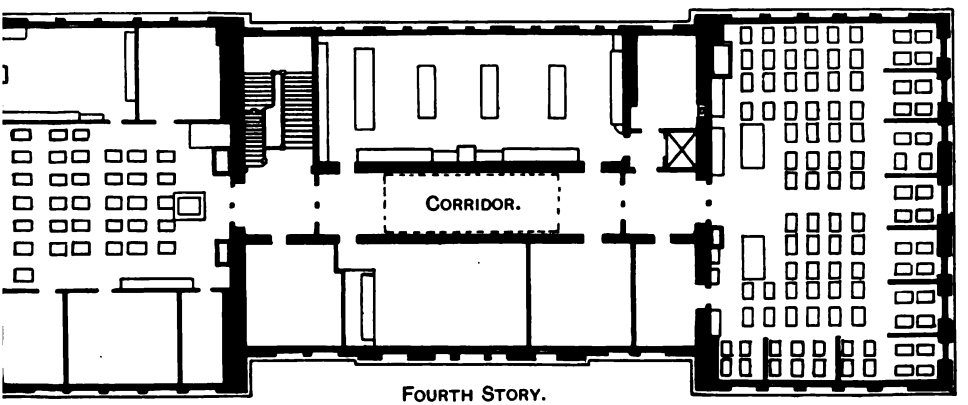
THE ARCHITECTURAL MUSEUM.



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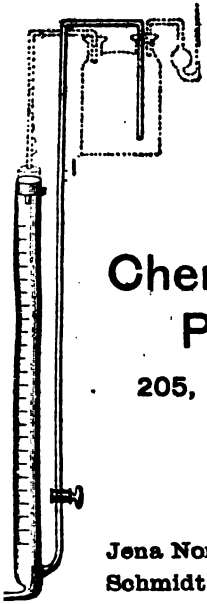

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